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OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 18, 1876.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 97 members and 11 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at its last meeting 6 persons were elected members of the Institute, and the following donations made to the Library:

Rose, H. Traité pratique d'analyse chimique. Paris, 1832. 2 Vols.

Mineralogie appliquée aux sciences chimiques. Girardin et Lecoq. Paris, 1826, 2 Vols.

Manual du mineralogiste. Paris, 1792. 2 Vols.
Essay par la voie seche. M. P. Berthier. Paris, 1834. 2 Vols.
Brard's mineralogie appliquée aux arts. Paris, 1821. 3 Vols.
Bache's System of Chemistry. Philad'a, 1819. 1 Vol.
Bullock's Fresenius Chemical Analysis. N. Y., 1844. 1 Vol.
Elemens de documastique. Paris, 1755. 4 Vols.
Sobrero & Barreswie. Appendice d'analyse Chimique. Paris, 1845. 1 Vol.
Lewis' Course of practical Chemistry. London, 1746. 1 Vol.
Ure's Dictionary of Chemistry. Philad'a, 1821. 2 Vols.
Bronginart's traité elementaire de mineralogie. Paris, 1807. 2 Vols.
Burat's Geologie appliquée. Paris. 1 Vol.
Daudenart's l'art de la vitrification. Paris, 1825. 1 Vol.
Accum's Practical essay on Analysis of Minerals. 1 Vol.
Chevreul's Recherches chimiques sur les corps gras. Paris, 1823. 1 Vol.
Manuel des pharmaciens et des droguistes (2 Vols. in 1). 1 Vol.
Cuvier. Le Regne animal &c. Paris, 1817. 4 Vols.
Rose, H. Handbuch der analytischen Chemie. Berlin, 1838. 2 Vols.
De Romé de l'isle. Cristallographie. Paris, 1783. 3 Vols.
Berzelius, J. J. Nouveau système de Mineralogie. 1 Vol.
Sage, M. Analyse chimique et concordance des 3 règnes. Paris, 1876. 3 Vols.
Beudant. Traité elementaire de Mineralogie. Paris, 1824. 1 Vol.
Liebig's Agricultural Chemistry, by Webster. Cambridge, 1842. 1 Vol.
Davis' Manual of Magnetism. Boston, 1848. 1 Vol.
Klaproth's Beiträge zur chemischen Kentniss der Mineralkörper. Berlin, 1795. 5 Vols.
Seel's Analysis of mineral waters, &c. 1838. 1 Vol.
Faraday's Manipulation Chimiques. Paris, 1827. 2 Vols.
Orfila, P. Traité des Poisons. Paris, 1818. 2 Vols.
Gay-Lussac. Cours de Chimie. Paris, 1828. 2 Vols.
Karten's Manuel de la Metallurgie du fer. Metz, 1830. 3 Vols.
Parnell's Elements of chemical analysis. London, 1842. 1 Vol.
Bergman's Manuel du mineralogiste. Paris, 1792. 1 Vol.
Berzelius, J. J. Essai sur la theorie des proportions chimiques, &c. Paris, 1819. 1 Vol.
Beudant's Traité elementaire de mineralogie. Paris, 1824. 1 Vol.
Dictionnaire technologique, &c., des arts et metiers. Paris, 1822. 24 Vols.

From Henry Seybert, Philadelphia.

Notes on Building constructions. Part 2. 1875. Encyclopædia of Chemistry. Parts 11–15. From J. B. Lippincott & Co.

Proceedings of the Davenport Academy of Natural Sciences. Vol. 1. 1867–1876. Iowa, 1876. From the Academy.

Report of the Meteorological Committee of the Royal Society for the year 1875. From the Society.

Minutes of proceedings of the Institution of Civil engineers. Vol. 45. Session 1875–76. Part 3. London, 1876. From the Institution.

Report on Machinery and Manufactures, with an account of European manufacturing districts, by Robt. H. Thurston. Wash., 1876. From the Author.

Third, Fourth and Eleventh annual reports of the geological survey of Indiana, made during the years 1871, 1872 and 1875, by E. T. Cox, State Geologist. Indianapolis, 1872 and 1876. With maps. From the Author.

Specifications and Drawings of patents issued from the U. S. Patent Office for April, 1876. Washington. From the U. S. Patent Office.

Plate glass, its manufacture in the United States, by W. F. Durfee and A. Gobert. Philada., 1876. From the Authors.

An account of the American Antiquarian Society, located at Worcester, Mass. From the Society.

Public Libraries in the United States of America, their history, condition and management. Special report. Dept. of Interior, Bureau of Education. Wash., 1876. From the Am. Library Association.

The Actuary also reported the following from the proceedings of the Board at its last meeting:

Mr. Wm. P. Tatham, chairman of the Committee on Exhibition, reported that in accordance with the action of the Board in May last, requesting the committee to correspond with other societies of like character in the Atlantic cities, with the view to quadrinal exhibitions in Boston, New York, Philadelphia and Baltimore, a correspondence was opened with the societies named, resulting in a conference of committees from the Massachusetts Charitable Mechanics' Association, of Boston, and the Maryland Institute, of Baltimore, with the Committee on Exhibitions of the Franklin Institute, at which conference the following Report was adopted:

"The Convention of the representatives of the following societies, to wit:

"The Massachusetts Charitable Mechanics' Association,

"The Franklin Institute,

"The Maryland Institute,

assembled at the room of the Franklin Institute, Machinery Hall, Centennial Exhibition, at the invitation of the Franklin Institute, upon the 23d of September, 1876, agree upon this report to their several constituent societies:

"*Whereas*, The Centennial Exhibition now in progress has presented to the people a model on such a grand scale that it must necessarily exalt the standard of such exhibitions, and enlarge public expectation with regard to them, and

"*Whereas*, Such expectations can best be satisfied by the united efforts of the societies named it is recommended:

(1) "That they abandon the system of annual or independent exhibitions heretofore pursued, which have to a certain extent interfered with each other, and agree to hold only one exhibition in each year by turns in the several cities of the seaboard.

(2) "To such exhibitions the members of all the societies shall have free admission under proper safeguards.

(3) "The exhibition in each city shall be at the expense and for the profit of the local society holding it and subject to all the rules and regulations imposed by the said society except as provided in the preceding paragraphs.

(4) "That, to secure some uniformity however, in the character and proceedings of the exhibitions, and with a view of affording an index of progress from year to year, the societies be recommended to unite in a classification of exhibits and a uniform system of appointing Judges. The classification of the goods to be based upon the position of each article in trade and not upon its use, so as to enable us to secure competent and expert judges of a whole class. The judges to be appointed one by each society for each class. The recommendations in this paragraph to be adopted or not by each society, at its option.

"Should variety be insisted upon, the principle of reciprocity to be adopted.

"(Signed) { JOSEPH L. BATES, *for Mass. Ch. Mech. Ass'n.*
W. P. TATHAM, *for Franklin Institute.*
JNO. M. CARTER, *on behalf of Md. Institute.*"

The Actuary further reported the following action of the Board:

"*Resolved*, that the following petition, duly signed by the President and Actuary, be presented to the City Councils:

"To the Select and Common Councils of the City of Philadelphia,

"The petition of the Board of Managers of the Franklin Institute, of the State of Pennsylvania, for the promotion of the Mechanic Arts, respectfully showeth,

"That the Franklin Institute is a corporation which for more than fifty years has labored with success for the object of its creation, by helping men to help themselves; by bringing together the men of science and the men of practice, to the instruction of both; by establishing a library, schools and lectures; by rewarding men of skill and ingenuity, and by exhibitions of their various productions.

"This last named purpose requires a hall far beyond the means of the Institute to command; and this is especially the case, since the Grand Model of the Centennial Exhibition has been seen by the people.

"Your petitioners, therefore, pray that Machinery Hall may be maintained and preserved for the purpose mentioned, as well as for such other public purposes as the proper authorities may direct."

And also, on motion of Mr. Fraley,

"*Resolved*, that notices of meetings be sent to all those members who are not more than one year in arrears for dues."

The President, having occasion to withdraw, here called Vice-President J. E. Mitchell to the chair, and he presided during the remainder of the meeting.

The Chairman introduced Capt. L. P. Sementschkin and Prof. Ashleyman, of the Royal Polytechnical Schools of Moscow and St. Petersburg; and the former gave explanations of the system of technical education in Russia.

The Secretary presented his report, which embraced illustrated descriptions of F. G. Fowler's Feathering propeller for steam vessels; Boynton and Adamson's Torpedo Boat; P. H. Dudley's Dynograph for determining Railway resistances; E. Dornheim's adjustable automatic fan for bedsteads; the ultimatum lamp burner for burning petroleum oils; and of a ball supported by a jet of steam at an angle of 40° from the perpendicular.

The Secretary called attention to the establishment by the Society of Arts of London, of a prize medal in Industrial Hygiene.

The Secretary made the following announcements:

The class in phonetic short hand having proved so successful (numbering now nearly seventy pupils), it has been decided to open

a day class for the accommodation of those who are unable to attend in the evening. The session of this class will be on Friday of each week, at 4 P.M., commencing on the 27th inst.

The time of opening the lecture season has been deferred until after the close of the Centennial Exhibition, and has been fixed for Tuesday, Nov. 14th.

The subject of the adoption of the Majority Report on the Metric System of Weights and Measures was called up, when, on motion, its further consideration was postponed to the next stated meeting.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

Continuation of List of Donations from the Meeting of the Institute held September 20th, 1876.

Fifty-sixth Annual Report of the Managers of the Apprentices Library Co. Phila, 1876. From the Company.

Ninth Annual Report of the Provost to Trustees of Peabody Institute. June 1, 1876. From the Trustees.

Laws governing the Steamboat Inspection Service. Washington, 1875. General Rules and Regulations prescribed by the Board of Supervising Inspectors of Steam Vessels and approved by the Secretary of the Treasury, 1875. Washington, 1875. From the Board.

Die Schmalspurige Montan—Bahn von Rostoken nach Marksdorf in Ungarn von Paul Klunzinger. Wien, 1875. Schnee Schutzvorkehrungen auf Amerikanischen und eurapäischen eisenbahnen. By E. Pontzen. Wein, 1874. Schlussbericht über den vorzunehmenden Ausban der Wasserstrassen in Frankreich, &c., &c. Wein, 1875. Uber hölzerne Brücken unter besonderm henweisse auf Amerikanische Gerust-brücken (Trestle Bridges), von E. Pontzen, Wien. Offentliche Bauten auf der Welt Ausstellung zu Paris im Jahre 1867. Besprochen von Ernest Pontzen. Wien, 1868. From the Author.

Specifications and Drawings of Patents, U. S. Patent Office, January, February and March, 1876. From the Commissioner.

Le Canal Maritime de Suez Illustré. Histoire du canal et des travaux par M. M. Fontane, Paris, 1869. Compagnie Universelle du Canal Maritime de Suez. 12em—19em Reunion, 1870—1875. Rapport de M. F. De Lesseps, &c., &c. From Prof. J. E. Nourse. Washington.

Elements of Physical Manipulation, by Edward C. Pickering. Part II. New York, 1876. From Hurd and Houghton, publishers.

Practical Treatise on the Construction of Iron Highway Bridges, for the use of town committees, &c. By A. P. Boller. 1876. From Claxton, Remsen & Haffelfinger, Philadelphia.

Notice du Plan en Relief du Canal Maritime de Suez. Exposé dans la salle de Lesseps Musée de Marine au Louvre. Paris, 1875.

The Maritime Canal of Suez. Brief memoir of the enterprise from its earliest date, &c., by Prof. J. E. Nourse. Washington, 1870. From the Author.

General Index of Official Gazette and Monthly Volumes of Patents of the U. S. P. O. for 1875. From the Patent Office.

Geological Survey of Canada. Report of progress for 1874–75. From the Director of the Survey.

Memoirs of the Geological Survey of India. Vol. XI, Part 2. Memoirs of the Geological Survey of India; Palæontology Indica; Jurassic Fauna of Kutch. Vol. 1—4. Ser. IX—4. The Cephalopoda. By Wm. Waagen, Ph. D. Calcutta, 1875. From the Office of the Survey.

Twenty-third Annual Report of the Managers of the State Lunatic Asylum, Utica, N. Y., for 1875. From the Managers.

American Iron Trade in 1876. Politically, &c., considered. By James M. Swank. From the A. I. & S. Asso., Phila.

Contribution to the Meteorology of Japan. By Thos. H. Jizard. From the Meteorological Committee, London.

On the Tides of the Arctic Seas. By the Rev. Saml. Houghton, M.D. From the Royal Society, London.

Monthly Report of the Department of Agriculture for July, 1876. Washington, 1876. From the Department.

Report of the Superintendent of the U. S. Coast Survey for 1873. From J. E. Hilgard, Assistant in Charge of U. S. C. S. Office.

Pennsylvania Archives, Sec. Ser., Vol. 4. Harrisburg, 1876. From J. B. Lynn.

An Address on some of the Leading Public Health Questions, by J. M. Toner, M.D. From the Author.

Etudes Electrochimiques des dérivés du Benzol, par Frederic Goppelsroeder. Mulhouse, 1876. From the Author.

Reports of the Commissioners of the U. S. to the International Exhibition, held at Vienna, 1873. 4 Vols. Washington, 1876. From the Secretary of State.

Educational institutions, Province of Ontario, Canada. Toronto, 1876. Home and foreign trade of Canada. By W. J. Patterson. Dominion of Canada. Catalogue of exhibits in Education Department. Toronto, 1876. From John Laidlow.

New South Wales, its progress and resources. Sydney, 1876. Mineral map and general statistics of New South Wales. Sydney, 1876. Official Catalogue of the natural and industrial products of New South Wales. Mines and mineral statistics of New South Wales, &c. Industrial progress of New South Wales, being a report of the

International Exhibition of 1870 at Sydney, &c. From the Commissioners of New South Wales, through their Secretary, Charles Robinson.

Memoria presentada al empresario constructor, Dr. D. Dioniso Derteano por V. A. Lastarria. Lima, 1876. El Departamento de ancachs y sus Riquezas minerals. Por A. Raimonti. Lima, 1873. From W. W. Evans, C.E., New York.

Woods and minerals of New Brunswick, &c., by Baily & Jack. From the authors.

Twentieth annual report of the Board of Trustees of water works, to City Council of Cleveland, &c., for 1875. From John Whitelaw, Supt. and Eng.

Annual report of the U. S. Geological and Geographical survey of the territories embracing Colorado, for 1873. By F. V. Hayden, Washington. From Secretary of Interior.

Annual report of the Secretary of Internal Affairs of Pennsylvania, for 1874–75. Pt. 3, Industrial statistics, Vol. 3. Harrisburg, 1876.

Tabulated results, compiled from the annual reports of Railroads, Passenger, &c., Co's of Pennsylvania, for the year ending December 31, 1875. From the Secretary of Internal Affairs.

British patent reports, issued between May 13th and July 29th, 1876. Abridgments of specifications relating to the manufacture of paper, pasteboard and papier mâché. Pt. II, A. D. 1858–1866. Second edition. London, 1876. Ditto Grinding grain and dressing flour and meal. A.D. 1623–1866. London, 1876. Ditto Purifying and filtering water, including the distillation of sea water to produce fresh water. A. D. 1675–1866. London, 1876. From the British Patent Office.

American Ephemeris and Nautical Almanac for the year 1876. Washington, 1876. From Prof. J. H. C. Coffin.

Report of the Meteorological office of the Dominion of Canada, for the year ended 31st December, 1875. From G. T. Kingston, Superintendent.

Annual Report of the Light House Board, to the Secretary of the Treasury, for the year 1875. Washington. Annual Report of the Supervising Architect, to the Secretary of the Treasury, for the year 1875. Washington. Catalogue of recently added books, Library of Congress, 1873–75, with index to subjects and titles. Washington, 1876. Maps of the U. S., showing extent of public surveys, &c., compiled from the official surveys of General Land Office, &c., under the direction of Hon. S. S. Burdett, Commissioner, 1874 & 75. From Hon. Chas. O'Neill, Philada.

Reports of the Commissioners of the United States to the International Exhibition, held at Vienna, 1873. 4 Vols. Washington, 1876. By R. H. Thurston. From the Author.

Five complete volumes and 20 numbers of the Journal Franklin Institute. From the Historical Society of Pennsylvania.

Announcement of Lectures to be given before the Franklin Institute at the Hall, commencing November 14th, 1876.

Six Lectures by Prof. Edwin J. Houston, on Light.
November 14th, 21st, 28th, Dec. 5th, 12th, 19th.

Eight Lectures by Prof. Wm. D. Marks, on Dynamics.
November 16th, 23d, December 7th, 14th, 21st, January 4th, 11th, 18th.

One Lecture by Mr. Henry Whitall, on Astronomy.
January 2d.

Five Lectures by Prof. Elihu Thomson, on Electricity.
January 9th, 16th, 23d, 30th, February 6th.

Eight Lectures by Dr. Horace Binney Hare, on Chemistry.
January 25th, February 1st, 8th, 15th, 22d, March 1st, 8th, 15th.

One Lecture by Mr. Robert Briggs,
on Prevention of Railroad Accidents.
February 13th.

Two Lectures by Mr. Alex. E. Outerbridge, Jr.,
on Metallurgy and Assaying of Precious Metals.
February 20th, 27th.

Three Lectures by Prof. Pliny E. Chase,
on Inventions, Ornamental Iron Work and Ceramics.
March 6th, 13th, 20th

The Lectures on Dynamics, by Prof. Marks, and on Chemistry, by Dr. Hare, form an elementary series upon the respective subjects.

The Warming and Ventilation of Churches.*—This is, in one respect, undoubtedly the most trying season of the year—not for weakly people alone, but for ordinary and even robust mortals, who are not proof against "catching cold" and the divers afflictions which in natural sequence frequently follow—in so far as by present structural arrangements it is impossible to regulate the temperature of churches, &c., where large numbers of people are assembled; and chiefly and naturally this difficulty is increased in the now chilly evenings. While the internal atmosphere is rising in temperature, the *ex*ternal is falling; hence the inflow of the cooling and denser air into the midst of the heating and rarifying atmosphere of necessity causes a strong and dangerous current of cold air to descend, in some particular parts of the building, on heated, and so, susceptible persons. Is it *quite* beyond the grasp of our architects to master this difficulty? In one of the churches of Torquay, being placed for some time near the cold limestone wall at the west end,

* From *The Builder*, London, Sept. 23, 1876.

which reaches up to the lofty roof, the downpour of cool air was so great that I moved my place, while others left the church, the strength of the current increasing as the service proceeded, and the atmosphere of the crowded church becoming continually more heated, forced the air into more rapid motion, naturally driving the expanded and lightened—because heated—air up to the roof, where, finding no escape, and becoming cooled by contact with the cool roof, it necessarily descended by the cold walls—the circulation thus set up being precisely that which takes place in boiling water in a vessel where the heat is applied beneath the centre only, as when a spirit-lamp is used, the water as it becomes heated ascending in the centre of the vessel and descending against the cooler sides. Is it impossible to contrive means to arrest these air currents? In a second church in the town, columns of cold air are let down from the clear-story windows on the devoted head of some unfortunate who is seated immediately beneath them, and to my cost I have found that through a heated, and therefore rarified, air, a column of cold, and therefore condensed, air will fall, with considerable force and weight. Last evening I had the misfortune to be placed within the arc which was formed by the horizontal projection of a stream of cold and heavy air from the window of a side aisle, on its passage to the floor.

These churches are the work of some of our leading architects, and yet, by these defects, are rendered not only unsuited to the purpose for which they were erected, but absolutely unsafe. And I cannot but think that a little study of the laws which govern these currents of air would lead to a remedy. Surely the present state of our churches and places of public assembly in this respect is a blot on the practice of scientific architecture.

Ancient Toughened Glass.—In a "Book of Curiosities" we read: "There was an artificer in Rome who made vessels of glass of so tenacious a temper that they were as little liable to be broken as those that are made of gold and silver. When, therefore, he had made a vial of the purer sort, and such as he thought a present worthy of Cæsar alone, he was admitted into the presence of their then Emperor Tiberius. The gift was praised, the skilful hand of the artist applauded, and the donation of the giver accepted. The artist, that he might enhance the wonder of the spectators, and promote himself yet further in the favor of the emperor, desired the vial out of

Cæsar's hand, and threw it with such force against the floor, that the most solid metal would have received some damage or bruise thereby. Cæsar was not only amazed, but affrighted with the act; but the artist taking up the vial from the ground (which was not broken, but only bruised together, as if the substance of the glass had put on the temperature of brass), drew out an instrument from his bosom and beat it out to its former figure. This done he imagined that he had conquered the world, as believing that he had merited an acquaintance with Cæsar and raised the admiration of all the beholders; but it fell out otherwise, for the emperor inquired if any other person besides himself was privy to the like tempering of glass. When he had told him 'No,' he commanded his attendants to strike off his head, saying, 'That should this artifice come once to be known, gold and silver would be of as little value as the dirt in the street.' Long after this—viz., in 1610—we read that, among other rare presents then sent from the Sophy of Persia to the King of Spain, were six mirrors of malleable glass so exquisitely tempered that they could not be broken."—*London Times.*

ENGINEERING ON THE SOUTHERN PACIFIC RAILROAD.

[From the *Mining and Scientific Press*, San Francisco, Cal., Sept. 9th, 1876.]

The event of driving the last spike in the railroad connection between San Francisco and Los Angelos, which occurred on Tuesday last, was one of great importance, indicating as it does the gradual opening up of southern California, Arizona, etc., and bringing them into more direct communication. The road passes through the San Joaquin valley, from Lathrop in the north (where the line branches from the Central Pacific), to Tehichipa, a distance of 300 miles, on almost a level. The work of track-laying was comparatively inexpensive, with bridges crossing the Stanislaus, Tuolumne, Merced, Fresno, and Kern rivers, and other streams flowing from the mountains to the San Joaquin. The San Joaquin Valley railroad, which comprises this section of the road, intersects the counties of Stanislaus, San Joaquin, Merced, Fresno, Kern and Tulare, and all the products of Tuolomne and Mariposa counties will find their way to market on this great highway.

The only natural passes across the barrier separating Los Angelos from San Francisco are the Tehichipa and Tejon passes, the former of which was chosen by the railroad engineers as the easier through which to run their track, and from there it debouches into the Mohave desert. These were not the only obstructions to be overcome, and the San Fernando tunnel, the longest on this side of the continent, had to be bored, and the work was performed with more than ordinary expedition.

San Francisco is now placed in communication by rail with Los Angelos, San Bernardino, Santa Monica, Wilmington, Anaheim and Santa Ana. Los Angelos is now the centre of an extensive railroad system, branches extending to Santa Monica, Wilmington and Anaheim, besides the main trunk of the Southern Pacific railroad, which runs through it. The branches extending to Wilmington and Anaheim are owned and controlled by the Southern Pacific railroad company; that to Santa Monica is the nucleus of the Los Angelos and Independence railroad. All that remains of the Southern Pacific railroad to be built is from Indian Wells to the Colorado river, at or near Fort Yuma.

The engineering difficulties in building this road were very great, and those encountered in ascending the Tehichipa canyon surpass anything encountered on an equal distance in the Sierra Nevada. Every artifice had to be employed to enable the engine to climb the steep grade, and within 19 miles there are 17 tunnels in ascending the Tehichipa. A few statistics regarding the length and size of these tunnels cannot prove uninteresting. Tunnel No. 1 is 245·8 feet long; No. 2, 232·2 feet; No. 3, 707·7 feet; No. 4, 257 feet; No. 5, 1,156·3 feet; No. 6, 303·7 feet; No. 7, 532·7 feet; No. 8, 690 feet; No. 9, 426·2 feet; No. 10, 406·6 feet; No. 11, 158·8 feet; No. 12, 756·3 feet; No. 13, 513·8 feet; No. 14, 512·7 feet; No. 15, 360·7 feet; No. 16, 262·5 feet; No. 17, 260·9 feet; making a total of 7,683·9 feet. Nearly all these tunnels are heavily timbered with staunch 11x14 inch red-wood timbers. At the bottom they are 14 feet in the clear, or 16½ feet in excavation. They are 22 feet in height, and the shoulders at the springing of the arch are 18 feet 4 inches. In the Soledad canyon there are two more tunnels, numbered 18 and 19, the first being 264 feet long, and the latter 332 feet. The longest tunnel on the coast is the San Fernando tunnel, 6,966½ feet in length.

This tunnel was commenced on March 27th, 1875, the headings met July 14th, 1876, and the timbering was completed August 9th, 1876. It is built on a slope of 37 feet to the mile, and is perfectly straight, so that one can see through it. It is not cut through a single mountain, as is the case with most undertakings of this kind, but runs through a succession of ridges and canyons. The entire length is 6,966 feet, or nearly a mile and a quarter. This is exclusive of the heavily graded approaches, which aggregate half or three-quarters of a mile more. The deepest point in the tunnel is 600 feet below the top of the mountain. The excavation is made in the form of a trapezoid, only that the top, which forms the longest side of the figure, is surmounted by an arch. The width of the bottom is 14 feet, the height of sides to the commencement of each, 16 feet, and the height to centre of arch 21 feet. The sides and top are protected by heavy timbers, braced, fitted and spiked into the aperture as soon as the earth is removed. The south approach ascends at a grade of two feet in 100, until it reaches the mouth of the tunnel, where the road bed strikes a uniform gradient of 71-100ths of a foot in 100, rising toward the north. At the northern extremity it reaches its highest point, and then descends with the same incline as the southern approach. Work was commenced simultaneously at both ends, and at three intermediate points on the line of the tunnel. From these points inclines were sunk to the level of the road-bed to further the work of excavation and provide ventilating facilities when the tunnel was completed. The tunneling was originally started some distance from the present face, but the overlying earth caved in so badly that it was found necessary to make excavations about sixty feet deep before sufficiently solid earth was found. Another obstacle which presented itself, was an excessive flow of water, rendering the work of excavating not only dangerous but very expensive.

Tunnel 9 is at the famous loop of Tehichipa pass. This loop completely encircles a mound, and by so doing gains a difference in elevation of 77 feet 6 inches. Emerging from tunnel 9, the train winds around the mound and passes directly over the tunnel at right angles, having made a curvature of 300° 52′. The length of the loop is 3,794 feet. Pictured on the map this loop looks like a coil thrown carelessly in a rope; it is a veritable corkscrew. It is claimed to be a novel and original achievement in engineering. The total

length of tunnels between Caliente and Los Angelos, as given above, is 15,246.4 feet.

The road has been built to within 100 miles of the Colorado river, which it will reach before the close of the year. The whole distance from here to Fort Yuma by the road is 715 miles, over 600 of which are completed.

HEAT-CONDUCTION IN GASES.

[From *English Mechanic and World of Science.*]

The power of different gases to conduct heat has in recent years been frequently studied, both in the way of theoretical calculation and of experimental measurement. The researches of M. Stefan have an important bearing on the theory of gases. Recently M. Winkelmann has published a new investigation of the subject in *Poggendorff's Annalen.*

For measurement of the heat-conduction, M. Winkelmann employed the same method as has been employed by other observers: he measured the velocity of cooling of a thermometric body within a vessel filled with the gas to be examined. The difficulty of these experiments lies in the circumstance that the cooling is caused not only by the conduction of the gas which surrounds the cooling body, but that also the currents of the gas, and above all, radiation, play an important part. M. Winkelmann considered it his chief task to eliminate the currents of the radiation; and he effected this in one case by altering the pressure of the gas between 760 and 1mm. (with decreasing pressure the action of gas currents becomes less). Secondly, he employed various apparatuses in which the cooling body within was always of the same dimensions and the same material, while the outer envelope was altered in size; the value of the radiation was then in all apparatuses the same, while the conduction varied with the size of the outer vessel, and so furnished data by means of which the radiation could be calculated and eliminated.

The results of these measurements are given in the following table:—

Gases.	Conductivity.
Air,	0·0000525
Hydrogen,	0·0003325
Carbonic acid,	0·0000317
Ethylene,	414
Marsh gas,	647
Nitric oxyde,	460
Carbonic oxide,	510
Oxygen,	563
Protoxide of nitrogen,	363
Nitrogen,	524

The numbers obtained for air and hydrogen, the gases with which the fullest series of experiments were made, further showed that in air, down to a pressure of 1mm., the heat-conduction is *independent* of the pressure; hydrogen, on the contrary, showed a quite divergent and hitherto unexplained behavior in reference to pressure, in that the changes of the currents with different pressures by no means afford an explanation of the observed differences in velocity of cooling.

For example, whereas with a lowering of the pressure from 750mm. to 91·4mm., there was a change of only 1·4 per cent. in the value for the velocity of cooling; on further diminution of the pressure to 4·7mm., there was a further decrease of 11 per cent., and this decrease continued when the pressure was further lowered to 1·92mm. Whether, perhaps, accidental circumstances may have operated here, or whether the phenomenon is due to properties of the gas, can only be decided by further and more exact researches.

A second task which M. Winkelmann set himself was to determine the relation of heat-conduction to temperature. In this investigation he had to employ new apparatus made of glass, and to effect the separation of the conduction from the radiation on a different principle from that in the first measurements. The observations were so arranged that first the time of cooling was determined from 18° to 8°, and then from 118° to 108°. With three apparatuses very different in their dimensions, M. Winkelmann obtained the temperature co-efficients 1·3661, 1·3429, and 1·3644, referring to the temperatures 7°·4 to 7°·6, and 107°·7 to 109°; that is to say, if the heat-conduction at the lower temperature be put equal to 1, then at the higher temperature it has the value just given.

Besides the two gases, air and hydrogen, carbonic acid was examined. If the latter changes its heat-conduction with temperature

in the same way as air and hydrogen, we should, by combination of the values of hydrogen and carbonic acid, obtain the same relative numbers as those given relating to hydrogen and air. The values so obtained, however, are altogether smaller, whence it appears that the conduction of carbonic acid is not dependent on temperature in quite the same way as that of hydrogen, but increases more quickly with the temperature.

Book Notices.

CHEMIA COARTATA, OR THE KEY TO MODERN CHEMISTRY, by A. H. Kollmyer, A. M., M. D., Prof. University of Bishop's College, etc. 1 Vol. 8vo, oblong. 107 pp. Lindsay & Blakistone, Phila., 1876.

The purpose of this book is to supply a reference text book of chemistry, and this end is reached in an exceedingly convenient and comprehensive way. The extended double page gives width of sheet, so that six or seven columns can be made to show at one view: 1st, the name of the element, followed by derived substances; 2d, some historic data; 3d, the sources from which obtained; 4th, the chemical equations of the sources and process of derivation; 5th, the chemical and physical qualities—the properties; 6th, the tests of most ready application or use. The author claims that "It will be found especially adapted to the wants of: 1st, students intending to present themselves for examination; 2d, persons who have learned the old notation and wish to become acquainted with the *modern system;* 3d, those who desire to keep up their useful knowledge of chemistry while actively engaged in other pursuits;" and this claim seems fully warranted. It is literally a handbook of chemistry, filling a want not supplied by other books, and not appreciated by other writers, and it will unquestionably meet with an extended sale and immediate use.

"DE LA TRANSMISSION ET DE LA DISTRIBUTION DES FORCES MOTRICES A GRANDE DISTANCE PAR A. ACHARD" C.E. Geneva, etc., extracted from the "Annales des mines" with additions. 1 Vol. 8vo. 156 pp., Dunod. Paris, 1876.

Attention is called to this work, so that any whose professional acquirements lead them to investigate the transmission of motive power by wire ropes, by compressed air or liquid pressure, will know where to look for a very complete study and exhibition both of principles and actual usage. The work is well worthy to be studied by every mechanical engineer, and its publication in separate form renders it available for the shelves of a library.

Civil and Mechanical Engineering.

HYDRAULIC RIVETING MACHINES.

By Wm. Sellers & Co.

In the earliest form of riveting machine, the riveting die was actuated either by a crank or a cam, so that the traverse of the die was uniform, and determined by this driving mechanism. The rivet, whether large or small, long or short, was compressed to the same length, often in rivet holes of varying diameters. Sometimes, therefore, the rivet did not fill the hole; sometimes the plates to be riveted were strained. The work was performed by gradual compression, in itself desirable, but the uniform traverse, operating upon irregular quantities in the rivet, and even forcing the metal into holes of varying capacity, failed to produce regular work.

The direct action steam riveting machine produces regular work with irregular quantities in the rivet or varying size of holes; but inasmuch as the work is done by a blow, the shock is, in time, destructive to the machine, and sometimes is injurious to the work.

Hydraulic riveting was first accomplished by a machine on which hydraulic pressure was employed to act directly upon a compressing piston, which carried the riveting die; but in all these hydraulic machines, a pump was employed to produce the pressure in the compressing cylinder, which cylinder was in communication with the pump chamber through a valve which was opened by the fluid whenever the pressure in the pump chamber exceeded that in the cylinder; consequently the compressing piston, which carried the die, was moved only when the pump moved to force the fluid through the valve, and rested when the pump was taking water for its next stroke. Hence the die might be stationary, while a rivet was but partially headed. Moreover, the compressing piston and die did not move at the will of the operator, but with the motion of the pump, whether it was worked by hand or power. If by hand, the workman had no means of controlling the pressure but by his judgment or strength;

if by power, a valve to release the pressure was provided, which could be opened by the operator whenever, in his judgment, a sufficient pressure had been exerted, but no means of determining this with any degree of accuracy was provided in either case, so that, although the pressure was gradual, and the traverse limited only by the performance of the work, the want of means to determine the latter produced irregular results.

Mr. Ralph H. Tweddell, of Sunderland, Great Britain, is the inventor of a hydraulic riveting machine in which is combined all of the advantages and which avoids all the difficulties which have characterized previous machine systems—that is to say, his machine compresses without a blow, and with a uniform pressure at will; each rivet is driven with a single progressive movement, controlled at will. The pressure upon the rivet after it is driven is maintained, or the die is retracted at will. And to this combination he adds features not heretofore found in any riveting machine.

This machine consists of a riveting die and a holder, one or the other attached to and moved by a piston in a cylinder, which is called the compressing cylinder; this cylinder communicating with an accumulator through a valve, not self-acting, but moved by the operator, so that when the valve is opened the piston to which the die or the die holder is attached invariably moves until the rivet is headed, with a force which is positively defined by the pressure on the accumulator. Hence the work is performed without a blow; the pressure is uniform whether the rivets are long or short; it can be modified by the weights applied to the accumulator; it is continuous for each rivet, and may be maintained as long as desired, or the riveting die can be retracted as soon as the rivet is finished, whether the pump is taking water, delivering it, or at rest.

The accumulator above alluded to is an essential part of the system; it is of variable capacity; in it water is kept under pressure, being forced in by means of a pump, or otherwise. The chamber of the accumulator is closed at one end, and to the other end is fitted a stuffing box, through which plays a weighted piston-rod or plunger. This plunger rises or falls as the quantity of water in the chamber increases or diminishes. By varying the load upon the plunger the pressure upon the water in the accumulator cylinder is adjusted. The water or other fluid under pressure on the accumulator, and there

stored up ready for use, is conveyed through suitable pipes and admitted by the operating valve to the compressing cylinder of the riveting machine, so that when the valve is opened the water flows into the compressing cylinder, closing the riveting dies upon the rivet, and finishing the work with just such force or pressure as the accumulator has been gauged to produce.

The plant required for hydraulic riveting consist, therefore, of an accumulator that can be loaded so as to give any requisite pressure per square inch; a means of keeping this accumulator full by pump or otherwise; and the riveting machine proper, which may be either stationary or movable within certain limits. For boiler work a stationary riveting machine, somewhat similar in construction to our steam riveters, has its large steam cylinder replaced by a very small hydraulic cylinder. The hydraulic cylinder closes the dies quickly, but without any blow.

For bridge work construction in the shop—the pump and accumulator are placed in any convenient position, and the water under pressure is carried through jointed or flexible pipes to a portable riveting machine suspended from an over-head carriage. In using this portable riveting machine the work resting on trussels remains stationary, the riveter is moved along it from rivet to rivet to be driven, performing the work with surprising rapidity and accuracy, and without noise or jar. The whole machine or combination is also arranged for use in the field, by providing a car with boiler, engine, pumps, and accumulator on it, the portable riveter being suspended from a crane or derrick attached to the car. This permits the use of the machine in driving the rivets in bridge erection or in ship-building.

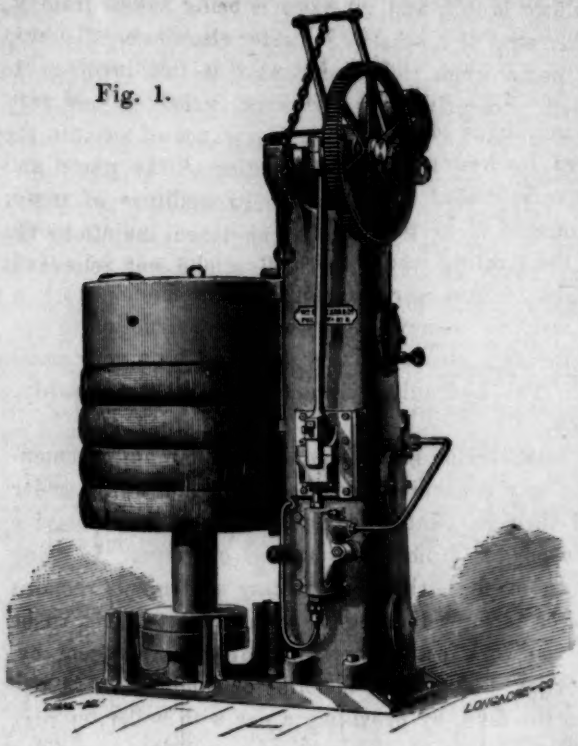
We have secured the control of this valuable invention, and are prepared to furnish the Tweddell hydraulic riveting machinery for any kind of rivet driving.

We have added to the original invention many improvements of our own, pertaining directly to it, and have arranged convenient over-head carriage and hoisting machinery to facilitate the use of the portable hydraulic riveting machine.

The following cuts and description will make the arrangement of hydraulic riveting machines more comprehensible to the reader:

ADJUSTABLE ACCUMULATOR AND PUMP.

Fig. 1.



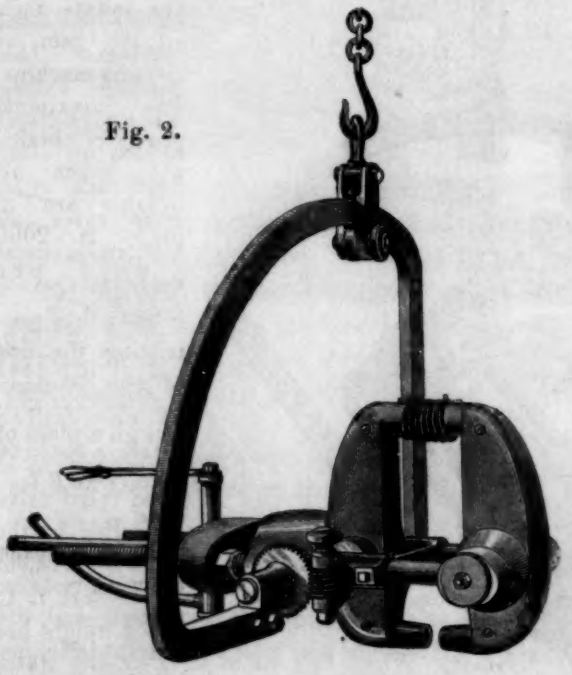
Arranged with weights suspended below the main casting, so made as to be readily released from it, to adjust the pressure to the work being done, each weight represents 250 pounds pressure per square inch on the ram of riveting machine. The maximum pressure obtainable when all weights are in place is 2000 pounds per square inch.

The pump, which is double-acting, operated by crank motion, is of improved construction, and takes its water from a reservoir in the upright. The return water in entering the reservoir passes through a mass of sponge to filter it. An important feature in the arrangement of pump and accumulator is the adaptation of our improved relief valve to the system. This valve is so constructed and controlled by the motion of the accumulator as to relieve the pump from work without stopping its motion when the accumulator is full, and to start it to pumping into the accumulator as soon as the accumulator weight has descended a short distance. When this valve is open, the water under pressure in the accumulator is shut off from the pump, and the pump relieved from pressure draws water from the reservoir and forces it back into the same reservoir, maintaining its action without

strain, but ready to resume its work when required. When the relief valve is closed, the pump forces water directly into the accumulator. When the accumulator is full, and no water is being taken from it, the pump must either stop or discharge its water elsewhere. To stop the motion of the pump when the accumulator is full, involves its being again started promptly when required, which is not very readily done, and risks the loss of water and entrance of air into the chamber while standing. To maintain the action of the pump and discharge under a safety valve involves the expenditure of power when no useful work is being done. Our arrangement maintains the motion of the pump ready for immediate action, and yet relieves it from strain when not required to do any work.

THE PORTABLE RIVETING MACHINE.

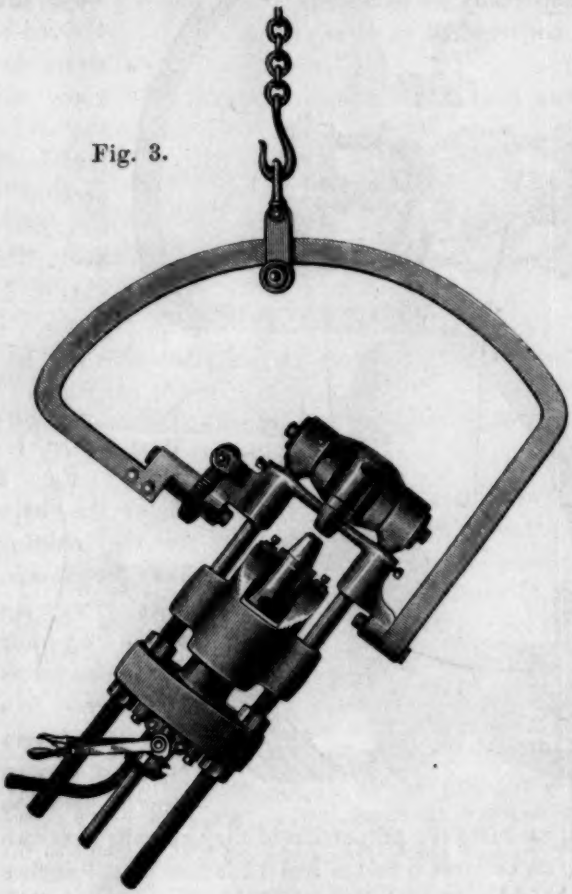
Fig. 2.



We give in Figs. 2, 3, and 4, this useful machine in three positions; showing how it may be adjusted to act readily on seams oblique, horizontal, or vertical. Fig. 2 shows the shape of the riveting jaws or levers. The rivet is driven by the dies in short ends of levers. We make these levers or jaws of various lengths, suited to different work. In all cases the proportion of the two ends is as two is to one. Thus, we make lever 6 inches and 12 inches long, 9 inches and 18 inches, or 12 inches and 24 inches. These proportions allow

plates to be riveted, where the rivets are five inches, eight inches or eleven inches from the edges of the sheets or the flange edges of angle, tee, or channel bars or beams. It is of course desirable, to avoid weight of the whole apparatus, to use the shortest and lightest levers adapted to the work in hand. For riveting boiler plates, the stationary machine with its long and massive stake, as before mentioned, is required. With the dimensions of levers which we have given, there is no trouble in obtaining strength, without passing the limit of portability for the machine, so that the pressure on the rivet shall cause the heated and plastic metal to flow into all irregularities of the rivet holes, while only the surplus of iron shall go into the heads.

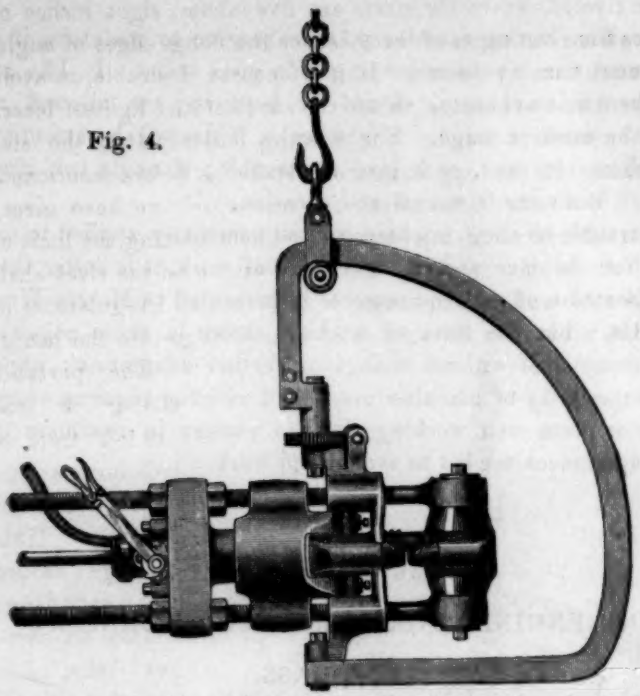
Fig. 3.



The portable riveter is suspended from a hoisting machine on an over-head carriage. This carriage having a longitudinal motion on over-head rails, of in some cases, 50 feet, and a transverse motion of 6 feet; thus permitting the use of the machine at any point within a space of 50 feet by 6 feet wide.

In this space the work rests on trussels, and the riveting machine is moved along or around it.

Fig. 4.



One man raises and lowers the riveter, adjusts it to the rivets, and then closes the dies on the rivets. Boys drop the red-hot rivets into place with the head of the rivet uppermost in horizontal work. With a skilful operator, as many as 6 to 10 red-hot rivets may be put in place ahead of him, and he can, on beam work, drive from 10 to 16 rivets per minute.

The portable hydraulic riveter is suspended from an over-head carriage; the hoisting machinery of this carriage is one of the improved forms of Weston's hoists, working with very little friction, and capable of nice adjustment of the riveting machine to any position.

The same carriage with slight alteration can be made to lift 1000 pounds, and, mounted on the same ways as carry the riveter carriage, can be used to lift and adjust the work to be riveted. To obtain the best result with these riveters, the extra hoisting machines are desirable.

In using the hydraulic riveting machine to advantage the rivets should be heated rapidly and uniformly. To accomplish this we have arranged furnaces inclosed in sheet iron covers, with every convenience for rapid handling of the rivets by the boys who attend to this part of the work.

The hydraulic riveting machinery is inexpensive to maintain, if a very little attention is paid to keeping it in good order. It, like all other hydraulic machinery, should be kept up; not allowed to deteriorate by careless usage. Slight leaks, if stopped by attention to the packing at once, will give no trouble; if neglected, may amount to serious wear from rust and abrasion.

As the portable riveting machine is most commonly applied to especial use, both in place and in description of work, it is better that a full consideration of the requirements be presented to Messrs. Wm. Sellers & Co.; but the form of machine shown in these pages is suited for many uses without change or further adaptation; while the great superiority of machine over hand riveting requires every large boiler or plate iron working shop to possess in readiness to use all the appliances needed to avoid hand work.

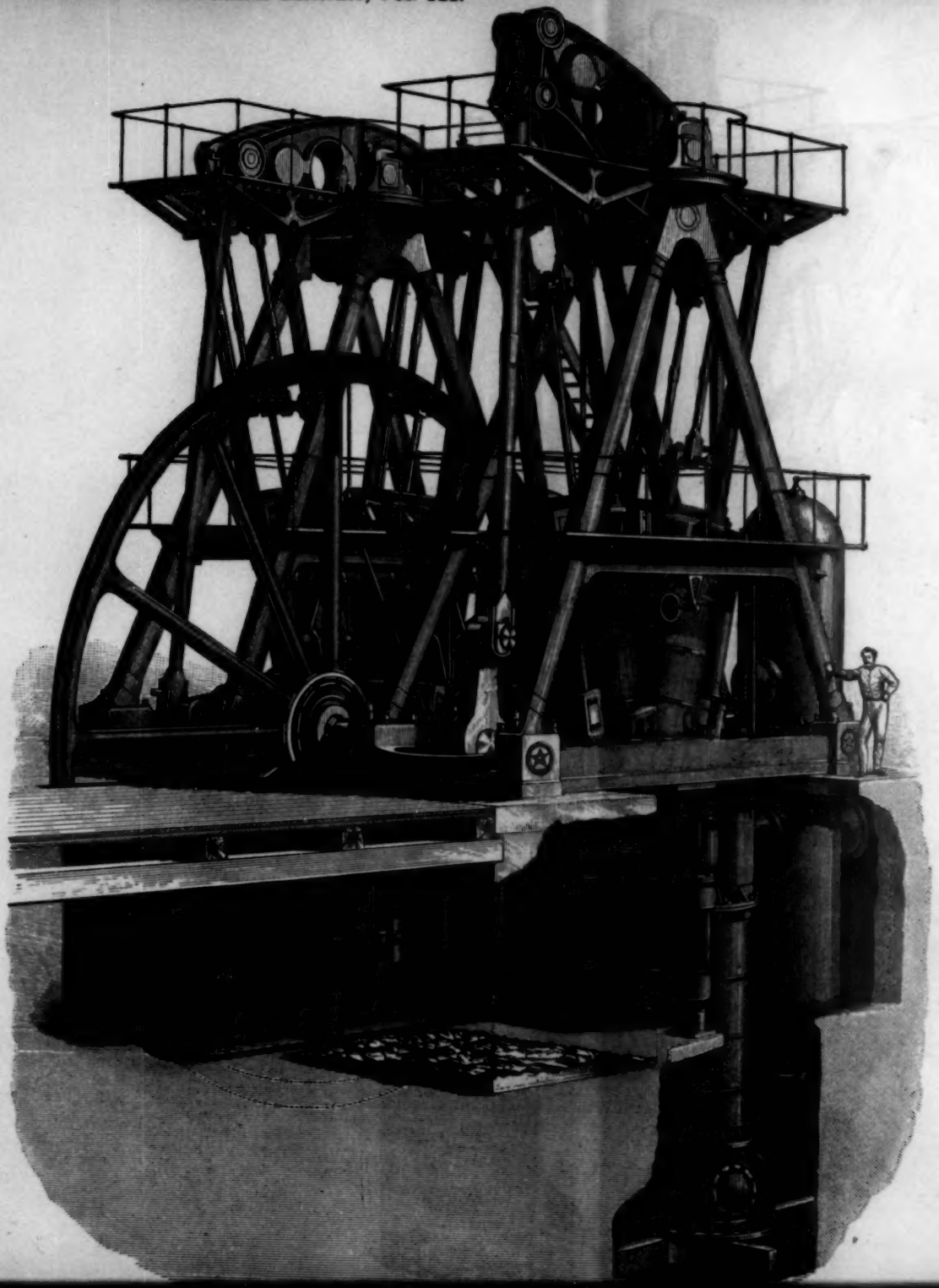
TRIAL OF THE

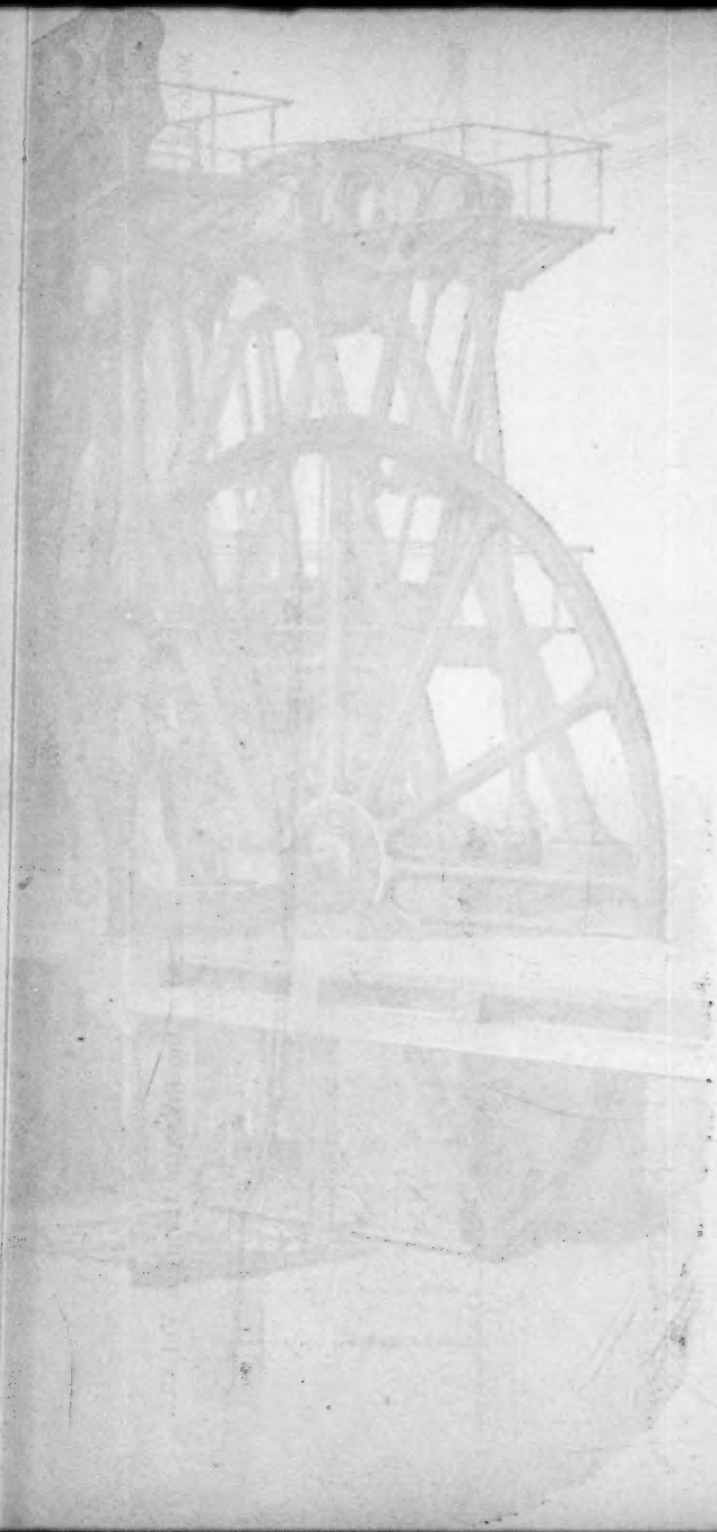
PUMPING ENGINES FOR THE WATER WORKS AT LAWRENCE, MASS.

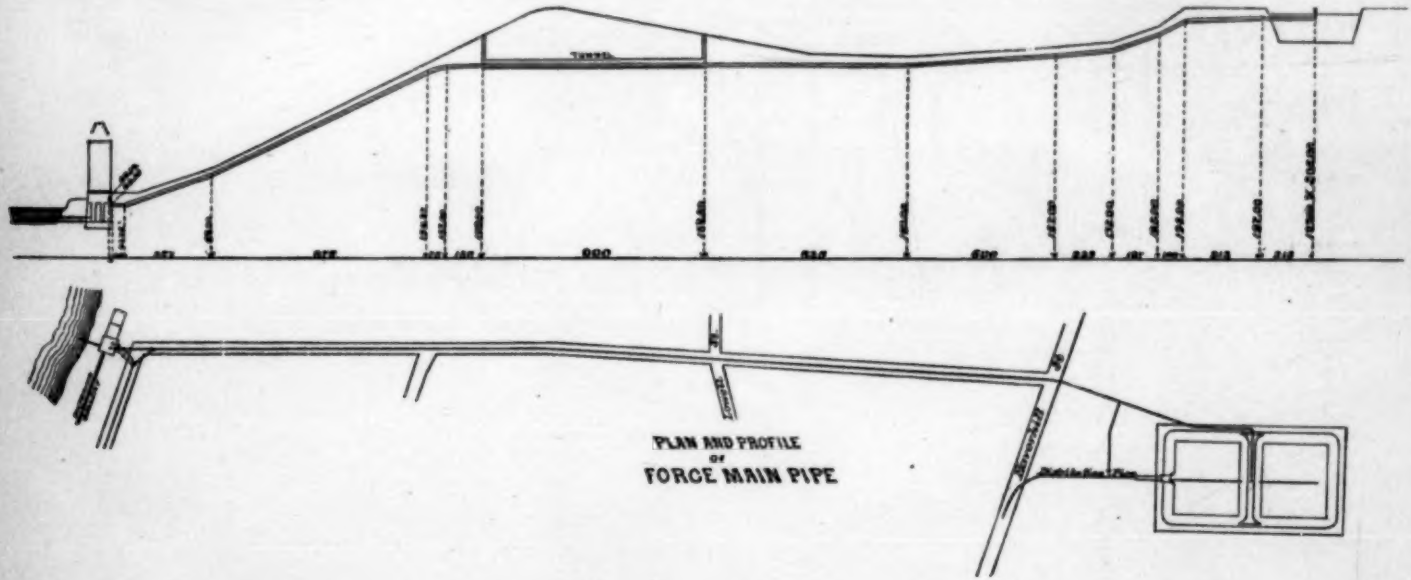
Designed and arranged by Mr. E. D. Leavitt, Jr., C.E.
Constructed by Messrs. I. P. Morris & Co., Philadelphia.

In accordance with the terms of contract between the Commissioners of the Lawrence Water Works and the builders of the boilers and engines, these engines have been subjected to a test trial under the supervision and direction of Messrs. Wm. E. Worthen, J. C. Hoadley and Jos. P. Davis, civil engineers, who were the chosen experts; and from the report made by them the following abstract has been prepared:

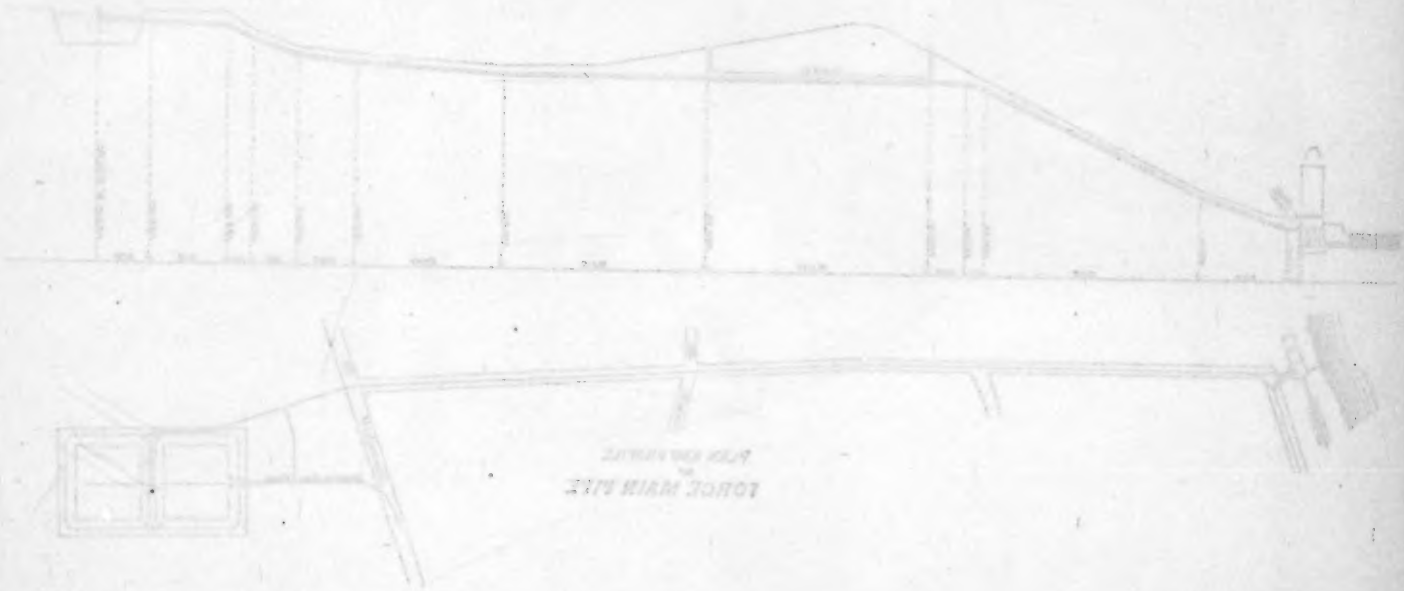
Description of Works.—Plate I contains plan and profile of engine-house, main and reservoir, by which their relative positions can be readily understood. The pumps of both engines deliver into branch mains of 24 inches diameter, and 75 feet long, thence by main 30 inches diameter and 4,900 feet long to reservoir. The delivery is usually by an overflow from the upright pipe on the centre of the division-wall of the reservoir; but, for the purpose of measurement

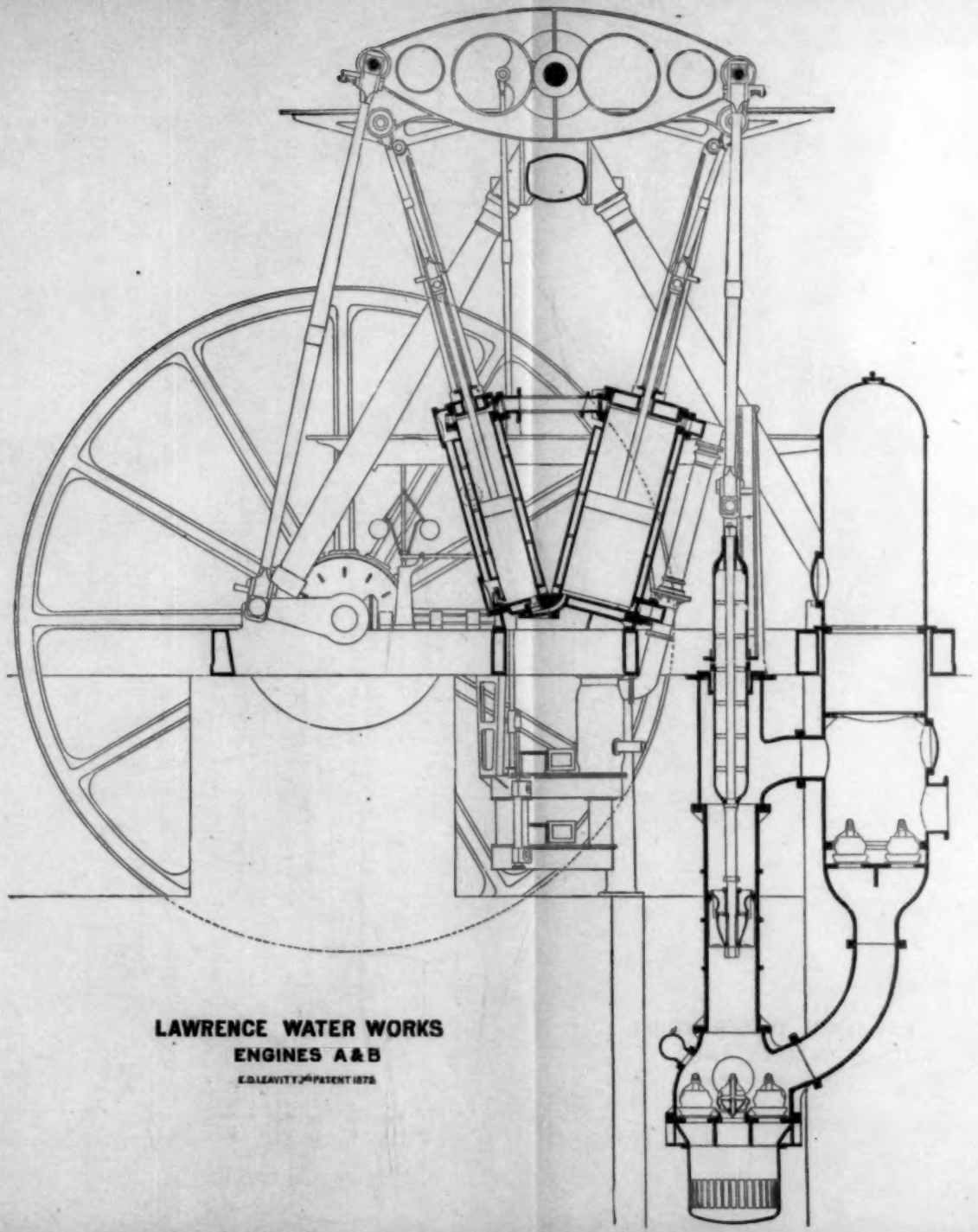


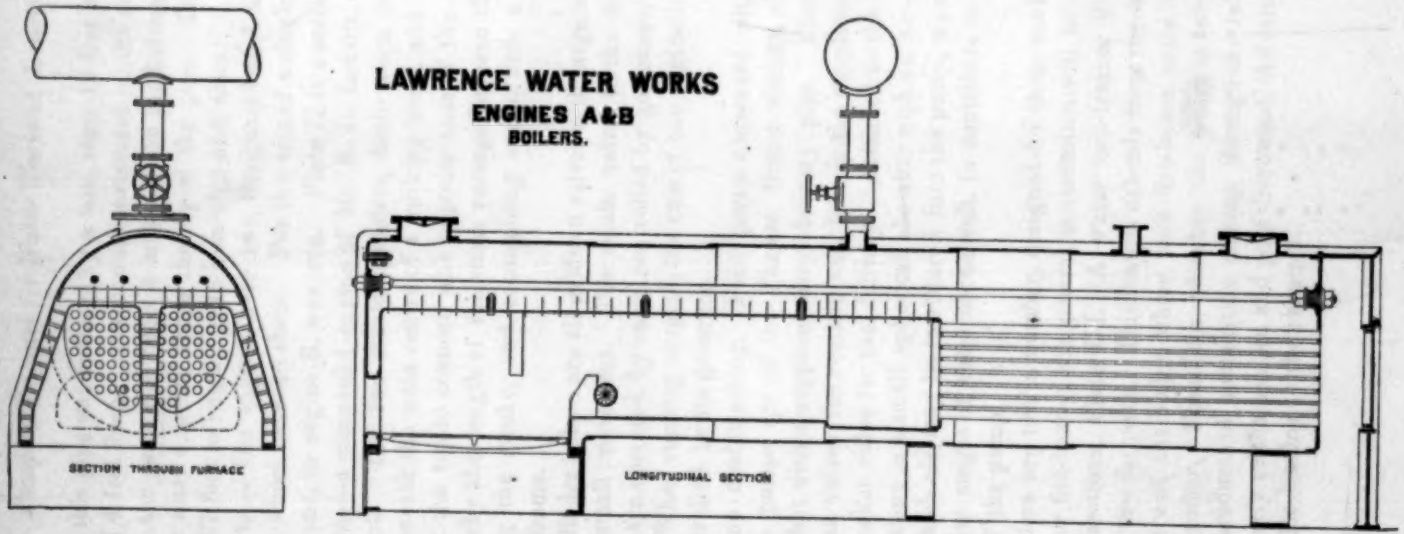


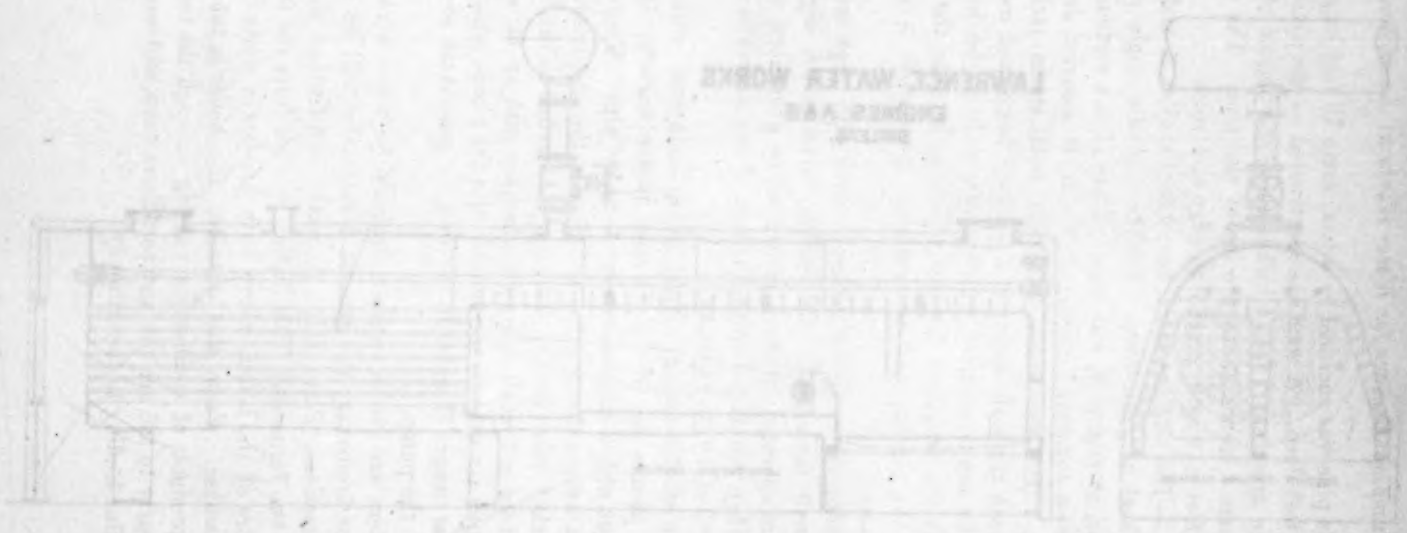


PLAN AND PROFILE
OF
FORCE MAIN PIPE




LAWRENCE WATER WORKS
ENGINES A&B
E.D.LEAVITT JR PATENT 1878


LAWRENCE WATER WORKS
ENGINES A&B
BOILERS.
SECTION THROUGH FURNACE
LONGITUDINAL SECTION



by weir, this pipe was enclosed by a box, some 10 feet long by 8 feet wide and 4 feet deep. A weir was constructed on the southerly side, of which the crest was 2 feet 4 inches above the bottom of the platform—or some 4 inches above the top of the pipe. The weir measured 3·997 feet in length, plate iron edge and sides.

ENGINES.—The engines were two, designated as A and B, with a single fly-wheel between them. For the test of a single engine, the westerly one, or engine B, was run. Plate II is a section of one of the engines—a compound engine of Mr. E. D. Leavitt, Jr.'s, design and patent. The two steam cylinders, both steam jacketed, are placed beneath the main centre of a working beam, and inclined outwardly at the top to connect with opposite ends of the beam, reducing thereby the length of the steam passage between the cylinders, equalizing the stroke, and economizing space, with a strong and compact frame.

The cylinder valves are all gridiron valves with large area of opening and small movement. The steam valves to the high-pressure cylinders are operated by cams controlled by governors, one to each engine. When running coupled, the cam of one engine is set and the other controlled by its governor.

Air-pump double-acting. Feed pump connected with air-pump rod. The pumps are of the Thames Ditton variety, bucket and plunger, but with a supplementary delivery pipe. There are seven double-beat valves for suction, and four in the supplementary pipe, and the bucket valve for the delivery. Attached to the lower valve chamber, there is a small spherical chamber with an air-cock at the top, by which air may be introduced into the pump, which is found, at particular stages of water in the well, to contribute to ease in the working of the pump.

The boilers are two in number, designed for these works, tubular, with interior fire-boxes; the general construction will be understood from the sections, Plate III. A water mid-feather divides each boiler into two furnaces. This feather extends from the front nearly to the centre of the boiler, where both fire-boxes unite in one combustion chamber. From this chamber the boiler is tubular to the end; the products of combustion passing through the tubes, return beneath nearly to the ash-pit, and pass downward, and latterly into a depressed flue leading to the chimney.

TABLE OF DIMENSIONS.

Diameter of high-pressure cylinders,	18	inches.
" low " "	38	"
" high " " rods,	$3\frac{1}{2}$	"
" low " "	4	"
" air-pumps,	15	"
" pump-barrel,	$26\frac{1}{2}$	"
" " plunger,	$18\frac{1}{2}$	"
" " " rod,	$4\frac{1}{2}$	"
" bottom and supplementary valves outside lower seat,	$15\frac{3}{4}$	"
" bottom and supplementary valves inside upper seat,	$12\frac{1}{2}$	"
" bucket-valves outside lower seat,	22	"
" " inside " "	15	"
" air-chamber,	54	"
" fly-wheel,	30	feet.
Length of stroke of steam and water pistons,	8	"
" " air-pump,	28	inches.
DISTANCES BETWEEN END CENTRES OF BEAM,	$16\frac{1}{2}$	feet.
Lead on steam-valves,	0	
" high-pressure exhaust valves,	$\frac{1}{16}$	inch.
" low " inlet,	$\frac{1}{16}$	"
" " " exhaust bottom,	$3\frac{5}{16}$	"
" " " " top,	$4\frac{9}{16}$	"
All measured on stroke of pistons.		
Cushion on high-pressure top exhaust,	$14\frac{1}{4}$	"
" " bottom "	$14\frac{3}{4}$	"
" low-pressure top "	$4\frac{1}{2}$	"
" " bottom "	$8\frac{1}{4}$	"

VOLUME OF CLEARANCE AND PORT SPACE:

High-pressure top,	·0256	of cylinder capacity.
" " bottom,	·0231	" "
Low " top	·0154	" "
" " bottom,	·0182	" "
Connecting pipe between cylinder	·0992	H. P. " "
Weight of fly-wheel,	35,900	lbs.

VOLUME OF CLEARANCE AND PORT SPACE:

Weight of walking-beam including pins and counter-balance,	25,700 lbs.
" high-pressure piston and connections,	2,575 "
" low " " " "	4,175 "
" air-pump " " "	1,800 "
" pump, plunger bucket,	7,200 "
" main connections, beam to crank,	3,800 "

BOILERS:

Length of shell,	25 ft. 5½ in.
" water mid-feather,	12 feet.
" combustion chamber,	3 "
" tubes,	10 "
Diameter of tubes,	3 inches.
Number "	80 "
Diameter of circular shell,	5 ft. 3 in.
Length of each grate,	5 feet.
Width " "	2 ft. 10 in.

Steam drum for both boilers, 12 feet 6×2 feet.

FORCE MAIN:

Length of force main,	4,900 feet.
Diameter " "	30 inches.

Branches from engines to main, 75 feet long×24 inches diameter.
Static lift from 165 feet to 174 feet.

That part of the contract which governed the Board of Experts in conducting the test trial is as follows:

"For the test the engines shall run for forty-eight consecutive hours, during which the water will be measured over a weir at the reservoir, and the delivery of the pumps must be at the rate of at least 2,000,000 of gallons in ten hours for each engine, with a speed of sixteen revolutions per minute, and a steam pressure in boiler of 90 pounds per square inch. If, however, the Water Commissioners shall so determine, the test shall last for a less time than forty-eight hours.

"The test shall be made under the direction of at least three mechanical engineers of good reputation, one to be chosen by the Commissioners, one by the said party of the second part, and the third by the other two.

"The coal to be used on the trial shall be of the best quality of Cumberland coal, and shall be carefully weighed, and with such precautions as the examiners may determine upon.

"The method of conducting the trials to be as follows: Steam to be raised in the boilers to the proper working pressure with clean fires of the usual thickness, when the engines are to be started, and the trial is to begin; but the beginning and ending of that portion of the trial on which all calculations of efficiency and duty are based shall be left to the decision of the experts.

"All the coal burned during the trial to be charged without deduction of any kind to the engines.

"The lift to be determined by a correct pressure-gauge attached to the rising main at a point within one hundred feet of the engine house, to the average readings of which shall be added the pressure due to the difference of the level of this point, and the mean surface of the water in the pump-well, and also an allowance of one pound per square inch for friction, and bends between the gauge and pump-well.

"The duty obtained must be equal to 95,000,000 pounds lifted one foot high for every 100 pounds of coal consumed in the boiler-furnaces during the trial, and said duty shall be reckoned upon the amount of water delivered over the weir at the reservoir, with five per cent. added thereto to allow for loss of action at the pump.

"At the close of the trial the fires to be in as good condition, and the water in the boiler at the same height, and the steam at the same pressure as at the beginning."

In preparation for the test a weir was constructed at the reservoir in the usual form, and with all the appliances of gauge-box, connecting-pipe, and hook-gauge. One side of the gauge-box was made of glass for better illuminating the point of the hook in the night.

The scales for weighing the coal were tested; and for determining the quantity fired at any time it was determined to use the car as provided for the works, running it back to the scales and reweighing after each firing.

By the terms of the contract, the first item to claim the attention of the experts was that "the coal to be used on the trial shall be of the best quality Cumberland coal, and shall be carefully weighed." All the precautions necessary for the careful weighing were taken by us, but the coal was of such quality of Cumberland as could be readily got; its evaporative capacity will be shown by the result of the experiments.

For measuring the water to be supplied to the boilers two tanks were constructed. The upper or measuring tank was a covered box, in the cover of which a small rectangular opening was made for an overflow; 1,400 pounds of water at 45° Fahr. were weighed into it, and by the dropping into the tank three bricks previously well wetted, the level of the water was brought up to the level of the overflow. The lower tank, from which the water was fed into the boilers, was provided with a glass gauge graduated from the upper tank. The graduation was from a full tank downward, so that the water

fed into the boilers was determined from the number of upper tanks discharged plus that drawn from the lower tank.

The steam gauges on boilers and steam and water on engine were those provided by the contractors. The accuracy of the important ones was determined by a comparison of them with a standard gauge of the American Steam Gauge Company, tested by a mercury column.

The thermometers and barometers used were furnished by Huddleston. The thermometers inserted in steam and water passages were made especially for the purpose, the bulbs being enclosed in a tube and the tube inserted into the steam, so that there was no pressure exerted on the bulb. Three thermometers were inserted, one in each of the steam-pipes near the boilers, one in the steam-pipe near the engine, one in each of the jackets of the high and low pressure cylinders, and one in the hot-well delivery-pipe. A tube closed at the lower end and filled with oil was inserted in the main flue for the reception of the thermometer.

A tank with a weir was provided for the reception of the condensed water, and of such capacity as not to be disturbed in its level by the discharge from the hot well.

Indicators were provided and attached to each end of both cylinders, and a pipe connection between the valve chambers of the pump with a T-pipe for the attachment of an indicator.

The gauge for determining the height or pressure of the lift was attached to the air-chamber, the readings were taken hourly, and corrected by comparison with a standard gauge. "The pressure due to the difference of level of this point (the gauge) and the mean surface of the water in the pump-well." A floating gauge was put in the pump-well, and referred to the same base as the gauge in the air-chamber. To determine "the amount of water delivered over the weir at the reservoir" a weir was carefully constructed at the reservoir, observations were taken at no longer intervals than five minutes during the trial, and the quantity estimated by the formula taken from Mr. Francis' "Lowell Hydraulic Experiments."

The Board of experts could have arrived at all the results required by the contract from a careful determination of the amount of coal used, of the pressure in the main referred to the level of the water in the well, and of the amount of water delivered at the reservoir, and following the method prescribed for firing. But it was considered

necessary that other data, usual in such tests, should be obtained, for comparison of these engines with others which have been previously tested under similar circumstances and also to exhibit, and satisfactorily explain, the final results arrived at.

At 4.16 P. M., May 1st, the fires were kindled beneath both boilers. At about 6 P. M. the engine was started, and the weir-box filled, and engine stopped to test the leak in rising main and weir-box. At 8.55 P. M. the engine was again started, and at 1 A. M., May 2d, full observations were commenced. The engine was then run continuously till 12.45 A. M., May 3d, when the pipe which had been inserted into the pump-chambers for the taking of indicator-cards blew out, and the engine was stopped till 2.19 A. M., May 3d, when the engine was again started and observations resumed, and continued without interruption till 2 P. M., May 4th, when your Board decided that the engine had been tested sufficiently, and it was stopped, and preparations made for running the two engines coupled.

The engines were coupled and started, and observations were commenced at 7 A. M., May 5th, and continued without interruption till 6 P. M., May 6th.

Hourly records of observation were made throughout the trial, with the average result* given in the accompanying tabular sheets, on which table I, columns 2 are the points of cut-off of the steam in decimals of the stroke, columns 3 the pressures of steam at the time of cut-off, columns 6 are the points at which compression commences in the exhaust lines in decimals of stroke, and columns 7, the pressures at this point. In this table of indicator cards, the pressures are referred to the zero-line as determined by observations of the barometer referred to the atmospheric line of the indicators. In the last column the net average pressures as determined by the planimeter are given.

Table II, columns 2, 3, 4 and 5, are the net average pressures as determined by the planimeter; column 6 is the reading of the gauge on the main corrected by the subtraction of 0·3 pound, the observed difference between this gauge and the standard; column 7 is the difference of level between the gauge and the hourly-observed level in the well, converting feet into pounds by dividing by 2·31; column 8 is the lift in pounds determined by the terms of the contract; column 9 is the total of coal, and column 10 the total of water as

* In the original report the figures are given as observed for every hour, in extenso.

TOP OF HIGH-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive) May 2d, 1876, = 17 consecutive hours.

Forward Stroke.				Backward Stroke.				At 0·05.		At 0·15		At 0·25.		At 0·35		At 0·45		At 0·55		At 0·65		At 0·75		At 0·85		At 0·95		Net Average.	Planimeter.
Initial.	Cut off at.	Pressure.	Final.	Initial.	Commencement of Compression	Pressure.	Final.	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−		
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26	27.	28.	29.	30.
99·62	·314	100·2	33·84	29·62	·836	9·19	51·47	100·27	27·1	100·74	10·12	100·72	10·	86·41	10·6	68·65	11·71	56·15	12·98	48·02	14·6	42·14	16·74	37·96	19·38	34·75	24·54	51·79	51·64

Average of hourly observations, 3 A. M. to 7 P.M., May 3d, = 17 consecutive hours; together with same from 5 A.M. to 2 P.M., May 4th, = 10 consecutive hours (omitting one hour). Total, 26 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
100·2	·307	100·4	33·4	28·35	·837	9·35	51·80	101·2	29·51	101·3	10·19	101·03	9·76	86·63	10·35	67·55	11·33	55·63	12·59	47·49	14·23	41·86	16·16	37·55	19·30	34·42	23·78	51·83	52·63

TOP OF LOW-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive) May 2d, = 17 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
26·14			6·14	4·32			.....	23·14	1·53	18·74	1·56	15·81	1·69	13·05	1·84	12·17	1·94	10·96	2·07	10·05	2·17	9·24	2·30	8·86	2·49	7·53	2·84	10·98	10·85

Average of hourly observations, 3 A.M. to 7 P.M., May 3d, = 17 consecutive hours; together with same from 5 A.M. to 2 P.M., May 4th, = 10 consecutive hours (omitting one hour). Total, 26 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
26·90			5·95	4·53			.....	23·26	1·54	18·78	1·61	15·88	1·65	13·77	1·82	12·18	1·98	11·05	2·05	10·06	2·15	9·30	2·26	8·60	2·43	7·78	2·78	10·97	10·76

BOTTOM OF HIGH-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive) May 2d, = 17 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
103·0	·315	102·4	34·9	28·6	·840	9·9	59·2	102·7	27·3	102·8	10·21	102·9	9·8	91·1	10·2	70·98	10·74	59·9	11·4	50·5	12·9	44·1	14·8	39·7	18·0	36·4	23·0	55·14	55·01

Average of hourly observations, 3 A.M. to 7 P.M., May 3, = 17 consecutive hours; together with five others taken between 9 A.M. and 2 P.M., May 4. Total, 22 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
101·2	·316	101·8	34·8	28·4	·842	8·3	60·92	101·37	26·77	101·87	8·87	101·95	8·68	90·89	9·22	71·36	10·0	59·2	10·19	50·95	12·79	44·56	14·79	40·06	17·91	36·41	22·67	55·67	55·90

BOTTOM OF LOW-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive), May 2d, = 17 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
28·4			5·42	3·44			8·25	22·04	2·74	17·11	1·85	14·17	1·88	12·12	1·9	10·7	2·07	9·72	2·05	8·97	2·14	8·29	2·22	7·76	2·44	7·06	2·57	9·66	9·89

Average of hourly observations, 3 A. M. to 7 P. M., May 3d, = 17 consecutive hours; together with same from 5 A. M. to 2 P. M., May 4th, =10 consecutive hours (omitting one hour). Total, 26 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
28·00			5·98	4·35			.....	22·03	2·94	17·20	1·96	14·17	1·94	12·10	1·91	10·69	2·01	9·68	2·10	8·91	2·21	8·19	2·31	7·69	2·38	7·07	2·78	9·51	9·50

TABLE No. II.

Averages and Totals, 8 A. M. to 12 P. M. (inclusive) May 2d, = 22 consecutive hours.

Revolutions by Counter.	High-Pressure Cylinder.		Low-Pressure Cylinder.		Gauge on Main in lbs.	Water Well below Gauge in lbs.	Total in lbs. + (1 lb. added).	Coal in furnaces, lbs.	Water fed into Boilers lbs.	Level of Water in Boilers in inches.	Temperature of Feed Water Deg. Fahr.	Pressure in Boilers in lbs.	Discharge into Reservoir in gallons.	Lift from Well into Reservoir.
	Top.	Bottom.	Top.	Bottom.										
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
21444	51·65	55·01	10·82	9·59	64·7	10·40	75·96	7266	60850	6·65	99	90	4527340	168·48

Averages and Totals, 4 A. M. May 3d, to 2 P. M. May 4th, = 35 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
34218	51·88	55·69	10·86	9·60	64·5	10·60	75·79	11630	95100	6·60	101	90	7261209	168·91

TABLE No. III.

	Gauges.				Temperatures.							Hygrometer.			Barometer.	
	At Engine.		Boilers.		Steam-pipe, D. Fahr.	High-Pressure Cylinder Jacket.	Low Pressure Cylinder Jacket.	In Flues.	Outside Atmosphere.	Boiler-House.	Water in Pump Well.	Wet Bulb.	Dry Bulb.	Humid.	Thermometer attached.	Barometer.
	Steam lbs.	Vacuum inches.	No. 1. lbs.	No. 2. lbs.												
	1.	2.	3.	4.	5.	6.	7.	8.	9.	19.	11.	12.	13.	14.	15.	16.
Practical Greatest,	93	28	94	94	332	331	328	410	58	77	48	66	72	77	57	30·26
" Least,	86	27	86	86	328	328	323	240	32	68	45	58	63	64	44	29·63
" Average,	89·5	27·5	90	90	330	330	326	325	45	72·5	46·5	62	67	70	50·5	29·94

it was fed upon the grates or into the boiler from hour to hour; column 11 was the hourly-observed level of the water in the boiler, referred to the crown-sheets of the fire-box instead of to the usual standard of a zero of common water level.

Column 14 is the hourly discharge of gallons of water into the reservoir as measured at the weir.

Column 15 is the absolute static height of the water over the weir above the level of the water in the pump-well. The crest of the weir and the gauge in the well were referred to the same base, and the column is made up from the hourly observations.

The footings of columns 2, 3, 4, 5, 8 and 15, are averages; of 9, 10 and 14, totals of pounds of coal used, of water fed, and of gallons of water delivered into the reservoir.

By the contract the coal was to be Cumberland, and the kind furnished was supposed to be of good quality; but, during the progress of the test, the evaporative results not being satisfactory, another lot was substituted, and fired from 5 P.M., May 3d, to 11 A.M., May 6th, with but little improvements in results. The ashes and cinders were weighed—978 pounds in the single engine tests, 435 pounds during the time the engines were coupled.

Table III gives the observations as taken of the pressure of gauges, temperatures by thermometers, saturation of atmosphere, and pressure by barometer. The caption sufficiently explains the position of the instruments. All the steam gauges were tested by Mr. Moore, of the American Steam Gauge Company; the one on the engine was verified by us, and found to be one pound short in the range from 80 to 95 pounds, so that one pound should be added to the readings in column one.

The thermometer in the flue indicated too low a temperature for the escaping gases, and 4 P.M., May 2d, all air-cracks into the flues were carefully closed.

It was thought advisable that the specific gravity of the water should be tested, which was done by Mr. Maurice Hasenclever, who reports as follows:

Specific gravity of Water as taken from the Engine-house.
Temperature 60° F.
(Compared with distilled water and 60° F. being 1·00000.)
Specific gravity = 1·004871.

Specific gravity of Reservoir Water, Temp. 57° = 1·005119.

The difference of 0·000245 is very near what theory allows for 3° F. expansion.

Observations were made of the flow at the condensed water weir at different times when the water was not directed into the measuring tank for the feeding of the boiler. The results, as given below, are in pounds per second:

May 2,	2.15	to	2.45	A.M.	10·86	lbs.	
"	4.20	"	4.45	"	11·32	"	at 101°
"	12.8	"	12 31	P.M.	11·41	"	" 101°
"	2.30	"	2.52	"	11·11	"	" 99°
"	4.	"	4.17	"	10·71	"	" 103°
"	10.7	"	10.31	"	11·16	"	
May 3,	4.10	"	5.25	A.M.	11·45	"	
"	10.57	"	11.47	"	10·92	"	
"	2.15	"	3.	P.M.	10·82	"	" 106°
"	3.	"	4.	"	10·59	"	" 109°
"	4.	"	5.	"	10·43	"	" 106°
"	5.	"	6.	"	10·34	"	" 106·5°
"	6.	"	6.45	"	10·39	"	" 106·5°
May 4,	3.40	"	3.50	A.M.	10·26	"	" 104 5°
"	6.2	"	6.15	"	10·58	"	" 105°
"	9.	"	9.32	"	10·13	"	" 106·5°
"	10.50	"	11.50	"	10.29	"	" 106·75°

CALCULATION FROM THE DATA OBTAINED.—*Duty per pound of coal in the steam cylinders, estimated from the indicator card:*

Diameter of high-pressure cylinders, . . 18″ area, 254·47 sq. in.
This will be effective area of bottom of piston; of the top it will be less the area of piston rod, or 254·47—9·62, . . . 244·85 "
Diameter of low-pressure cylinder, . . . 38″ area, 1134·11 "
Top area of piston, 1134·11—12·57, . . 1121·54 "

During the 22 hours, from 2 A.M. to 12 P.M., May 2d, the average pressures by planimeter, Table V, were:

Top of high pressure cylinder, ... 51·65
Bottom " " " . . . . . 55·01
Top of low " " . . . . . 10·82
Bottom " " " . . . . . 9·59

Top high pressure,	51·65 × 244·85 =	12646·5		
Bottom " "	55·01 × 254·47 =		13998·4	
Top low pressure,	10·82 × 1121·54 =	12135·1		
Bot. " "	9·59 × 1134·11 =		10876·1	
		24781·6	24874·5	49656·1

The length of stroke was 8 feet, the number of revolutions, 21,444, and coal consumed, 7,266 pounds.

$$\frac{49656{\cdot}1 \times 21444 \times 8}{7266} = 1{,}172{,}365 \text{ pounds feet per pound of coal;}$$

since 1 H. P. = 1,980,000 pounds feet per hour.

$$\frac{1{,}980{,}000}{1{,}172{,}365} = 1\,69.$$

That is, 1 indicated horse power for every 1·69 pound of coal fed upon the grates.

During the 35 hours, from 3 A.M., May 3d, to 2 P.M., May 4th, the average pressures in the steam cylinders were:

Top of high pressure cylinder, . . .	51·88
Bottom " " " . . .	55·69
Top of low " " . . .	10·86
Bottom " " " . . .	9·60

Top high pressure,	51·88 × 244·85 =	12702·8		
Bot. " "	55·69 × 254·47 =		14171·4	
Top low pressure,	10·86 × 1121·54 =	12179·8		
Bot. " "	9·6 × 1134·11 =		10887·4	
		24882·6	25058·8	49941·4

The number of revolutions was 34,218, coal consumed, 11,630 pounds.

$$\frac{49941{\cdot}4 \times 34218 \times 8}{11630} = 1{,}175{,}508 \text{ pounds feet per pound of coal;}$$

$$\frac{1{\cdot}980{\cdot}000}{1175508} = 1{\cdot}684 \text{ pounds per hour, per 1 indicated H. P.}$$

In the early part of this report the duty per pound of coal determined by the terms of the contract on the main was:

For the 22 hours, ...	962·019 pounds feet.
" 35 "	961·776 " "

During the 34 hours of trial of the engines running coupled, the average pressure was 77·73 pounds; the gallons discharged into the reservoir, 11,450,593; coal consumed, 18,411.

$$1{\cdot}05 \times \frac{(77{\cdot}73 \times 2{\cdot}31) \times (11450593 \times 8{\cdot}38)}{18411} = 982617 \text{ pounds feet}$$

per pound of coal.

Comparison of the static head of the water over the weir above the level of the water in the well, with the head determined according to the terms of the contract:

For 22 hrs., May 2,		Static head, .	168·48
		Contract, . .	$75·96 \times 2·31 = 175·47$
" 35 " "	3 and 4,	Static head, .	168·91
		Contract, . .	$75·79 \times 2·31 = 175·07$
" 34 " "	5 and 6,	Static head, .	169·66
		Contract, . .	$77·73 \times 2·31 = 179·56$

Comparison of the measured capacity of the pump with the delivery into the reservoir.—No measurements of the interior of the pump-barrels were taken by the experts. The measures have been taken from the notes of Mr. Leavitt. Diameter of pump-bucket, $26\frac{1}{8}$ inches; area, 536·05; stroke, 96 inches.

$$\frac{536·05 \times 96}{231} = 222·77 \text{ gallons per revolution.}$$

In the 22 hours, $\frac{4527340 \text{ galls.}}{21444 \text{ revols.}} = 211·12$ gallons per revolution; ·948 of measured capacity.

In the 35 hours, $\frac{7261209 \text{ galls.}}{34218 \text{ revols.}} = 212·2$ gallons; ·952 measured capacity.

In the 34 hours, $\frac{11450593}{27248 \times 2} = 210·11$ galls.; ·943 measured capacity.

Evaporation.—The quantities of water measured at the tanks are not exactly the quantities evaporated in the boilers, as it will be observed that the levels of water in the boilers are not the same at the ends of the tests as at the beginning. A correction must therefore be applied.

For the data for this calculation there was assumed a uniform pressure in the boiler of 90 pounds, 330° of temperature, of feed-water of 100°, of total in steam, 1214°, in all the tests. The cubic contents of each boiler, for the single inch between 6″ and 7″, we estimate at 10 cubic feet, and the weight at 605 pounds. In the 1st and 3d tests the level of water in the boiler at the end of tests was 5″ and 7″ higher than at the beginning, or there were 605 pounds in one, and 847 pounds in the other, more than at the beginning, which was not evaporated, but had been raised from the temperature of feed-water, 100°, to temperature of water in boiler, 330°; the net deduction we therefore make 480 pounds.

In the 3d test, in the same way, we make the net deduction to be 672 pounds.

In the 2d test, 35 hours, the water in the boiler at the end of the test was 1·5″ lower than in the beginning; 1210 × 1·5; 1815 pounds had been evaporated, which had not during the test been measured in the tanks. But this water had not been evaporated from the temperature of the feed-water, 100°, but from that of the boiler water, 330°, equivalent to 1440 pounds evaporated from 100°, which should be added to amount given in the table.

The water was weighed into the measuring tank at 45°, and taken from it for the boilers at 100°. The last columns are the pounds of water corrected for this difference in temperatures.

	Coal.	Water from Tanks.	Correction.	Water Evaporated from 100°.		
				Total.	Per Pound of Coal.	Actual Evaporation per Pound of Coal.
1st test 22 hrs.	7,266	60,852	—480	60,370	8·31	8·27
2d " 35 "	11,630	95,100	+1,440	96,540	8·31	8·27
3d " 34 "	18,411	161,330	—672	160,658	8·73	8·69

At the time of the tests, the preparations were not sufficiently complete to measure the water condensed in the jackets, and this was made the subject of an after examination by Mr. Hoadley, May 23d, using the tank for water of condensation as a measure. Reading by the hook gauge, he found that from 11 A.M. to 5 P.M. the water rose from ·0155 foot to 1·7700 or 1·7545 feet, or at the rate of ·2924 foot per hour for 6 hours. The area of tank, including gauge-box, was 19·186 square feet. The mean temperature of water, 188°; weight per cubic foot, 60·4167 pounds.

$$19186 \times \cdot2924 \times 60\cdot4167 = 338\cdot85 \text{ pounds per hour,}$$

as the water condensed in the jackets of the cylinders, engine B.

But exactly the same conditions did not obtain as during the test. The pressure carried in the boilers at this time was from 70 to 75 pounds, and the observed temperature in the low-pressure cylinder jacket at 75 pounds was 315°. At the time of test there was an average of about 326° under 90 pounds pressure.

Coal Consumed per Hour per Square Foot of Grate.—During the 1st and 2d tests, of 22 hours and 35 hours, although both boilers were used, the grate surfaces were reduced by a brick bridge on the rear of the bars, which were removed in the 3d test, when the engines

ran coupled. The net area of grate surface in the 1st and 2d tests was 47 square feet; in the 3d, 58¾ square feet.

Coal Fed per Hour.—

1st test, $\frac{7266}{22} = 330\ 3$ $\frac{330\ 3}{47} = 7{\cdot}03$ pounds per sq. foot of grate.

2d " $\frac{11630}{35} = 332{\cdot}3$ $\frac{332{\cdot}3}{47} = 7{\cdot}07$ " " " "

3d " $\frac{18411}{34} = 541{\cdot}5$ $\frac{541{\cdot}5}{58{\cdot}75} = 9{\cdot}22$ " " " "

Comparison of curves as given by the indicator with theoretical, adiabatic, and isothermal curves. A set of indicator cards, from both ends of both cylinders, were very carefully divided and measured by Mr. Hoadley, of our Board, and replotted, the low pressure cylinder at bottom, in connection with high pressure bottom, and the low pressure top with high pressure top, all volumes being represented in the terms of volumes of high pressure cylinder. On these cards, thus constructed, isothermal and adiabatic curves and lines of temperatures are plotted. The indicator cards and comparative cards are given in the accompanying figures, with the tables of volumes, temperatures, and pressures, on which the comparative cards were constructed, and which will be sufficiently explanatory of each other.

The Board of Experts report, as the result of their examination, as to the fulfilment of the requisitions of the contract, that: From 2 A.M. to 12 midnight, May 2d, 22 hours, there were delivered into the reservoir, as measured by the weir observations taken at intervals of not more than five minutes, 4,527,340 gallons,

or 2,057,881 gallons for each ten hours.

Revolutions, 16·25 per minute; boiler pressure, 90 pounds.

From 3 A.M., May 3d, to 2 P.M., May 4th, 35 hours, the delivery into the reservoir, measured as before, was 7,261,209 gallons,

or 2,074,681 gallons for each ten hours.

Revolutions, 16·29; boiler pressure, 89 pounds.

The contract is for

2,000,000 gallons in ten hours for each engine,

with a speed of 16 revolutions per minute, and a steam pressure in boiler of 90 pounds per square inch.

DUTY.—The lift, as determined by the terms of the contract, was in the 22 hours' test of May 2d, 75·96 pounds, or $75{\cdot}96 \times 2{\cdot}31 = 175{\cdot}47$ feet.

LAWRENCE WATER WORKS,

May 4th, 1876.

INDICATOR DIAGRAMS, LOWER END.

High-pressure cylinder, 18 in. diameter, 96 in. stroke. Volume 24429 cubic in. = 14·13715 cubic ft. Clearance, 564 cubic in. = 2·31 per cent.

Low-pressure cylinder, 38 in. diameter, 96 in. stroke. Volume, 108874 cubic in. = 63·0058 cubic ft. Clearance, 1977 cubic in. = 1·82 per cent.

Difference of volume of cylinders, 108874 — 24429 = 84445 cubic in.

Clearance of low-pressure cylinder, and difference of volume of cylinders, expressed in terms of volume of high-pressure cylinder, as follows:

1977 ÷ 24429 = ·080928 = 8·09 per cent.

84445 ÷ 24429 = 3·4567.

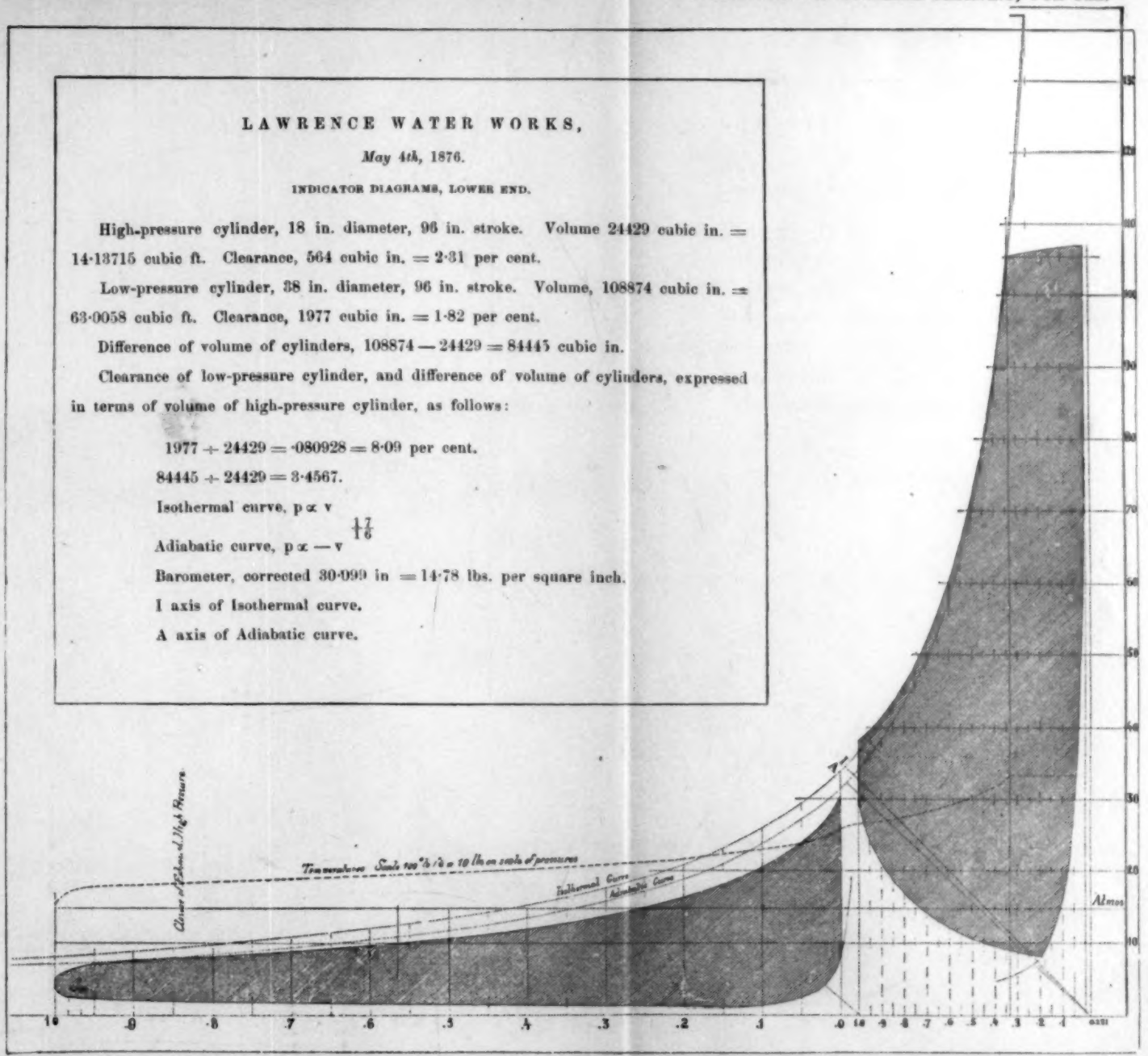
Isothermal curve, $p \propto v$

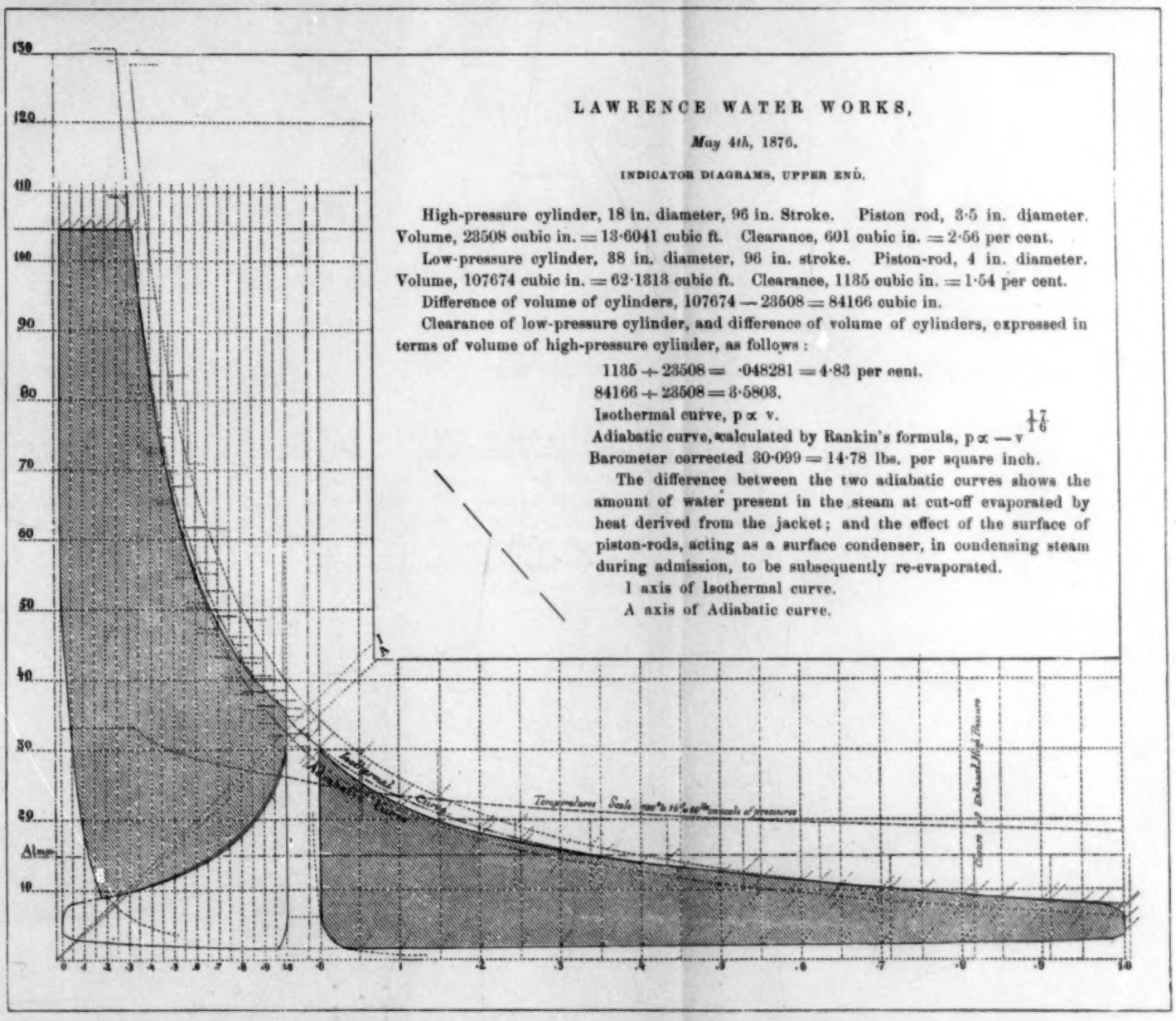
Adiabatic curve, $p \propto -v^{\frac{17}{16}}$

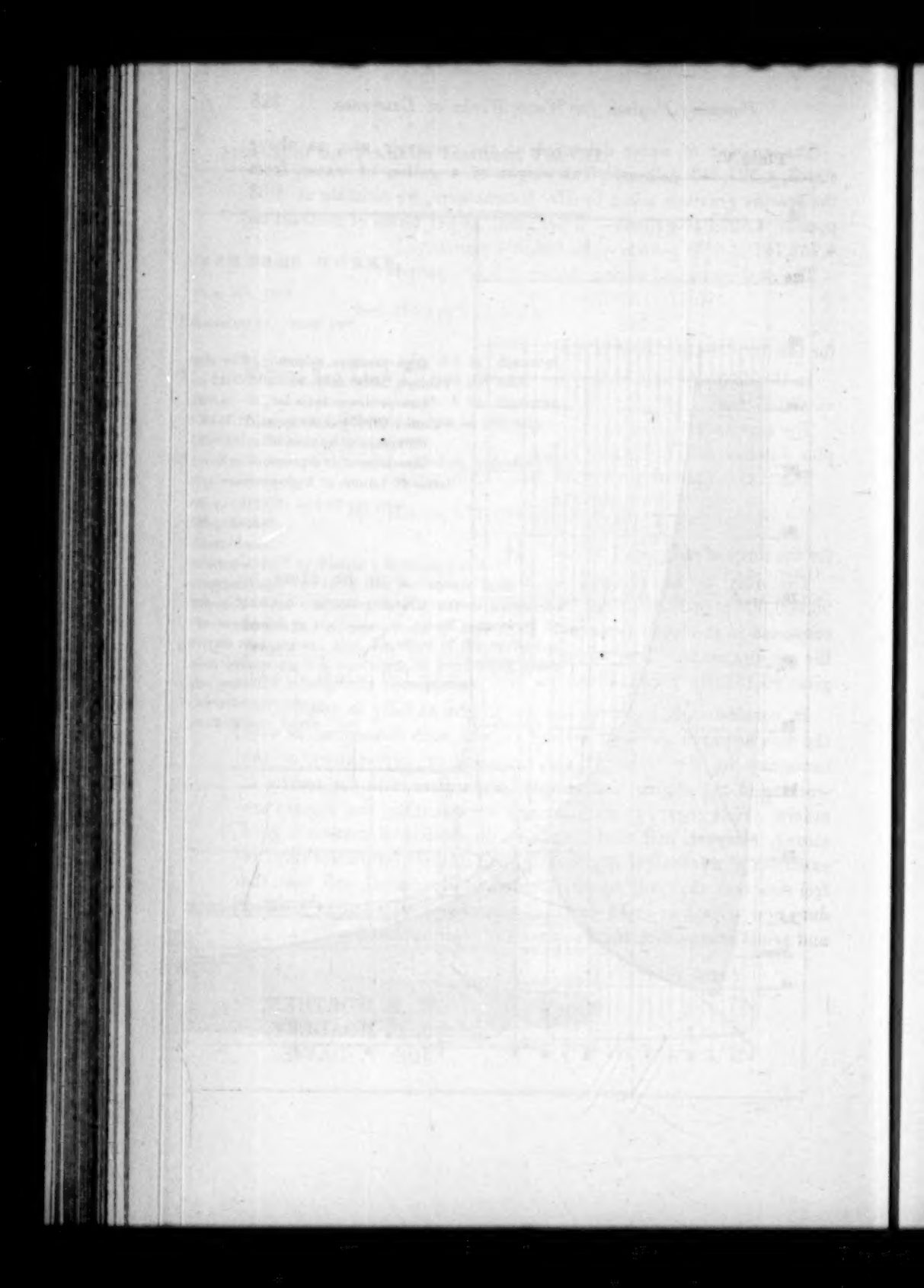
Barometer, corrected 30·099 in = 14·78 lbs. per square inch.

I axis of Isothermal curve.

A axis of Adiabatic curve.




LAWRENCE WATER WORKS,
May 4th, 1876.
INDICATOR DIAGRAMS, UPPER END.
High-pressure cylinder, 18 in. diameter, 96 in. Stroke. Piston rod, 3·5 in. diameter. Volume, 23508 cubic in. = 13·6041 cubic ft. Clearance, 601 cubic in. = 2·56 per cent.
Low-pressure cylinder, 38 in. diameter, 96 in. stroke. Piston-rod, 4 in. diameter. Volume, 107674 cubic in. = 62·1313 cubic ft. Clearance, 1185 cubic in. = 1·54 per cent.
Difference of volume of cylinders, 107674 — 23508 = 84166 cubic in.
Clearance of low-pressure cylinder, and difference of volume of cylinders, expressed in terms of volume of high-pressure cylinder, as follows:
1185 ÷ 23508 = ·048281 = 4·83 per cent.
84166 ÷ 23508 = 3·5803.
Isothermal curve, p ∝ v.
Adiabatic curve, calculated by Rankin's formula, p ∝ — v
Barometer corrected 30·099 = 14·78 lbs. per square inch.
The difference between the two adiabatic curves shows the amount of water present in the steam at cut-off evaporated by heat derived from the jacket; and the effect of the surface of piston-rods, acting as a surface condenser, in condensing steam during admission, to be subsequently re-evaporated.
I axis of Isothermal curve.
A axis of Adiabatic curve.
130
120
110
100
90
80
70
60
50
40
30
20
Atmos
10
Temperature Scale
Curve of Actual Work Pressure



The amount of water delivered at the reservoir was, as above stated, 4,527,340 gallons. The weight of a gallon of water, from the specific gravities taken by Mr. Hasenclever, we estimate at 8·38 pounds, 4,527,340 gallons + 5 per cent., as per terms of contract = 4,753,707 × 8·38 pounds = 39,836,064 pounds.

The coal consumed during the time, 7,266 pounds:

$$\frac{175{\cdot}47 \times 39836064}{7{,}266} = 962{,}019 \text{ pounds feet}$$

for the duty of one pound of coal.

In the 35 hours' test of May 3d and 4th, the lift was 75·79 pounds = 175·07 feet.

The amount delivered at the reservoir was 7,261,209 gallons, and plus 5 per cent. = 7,624,269 gallons, or 63,891,374 pounds.

The coal consumed during the time 11,630 pounds:

$$\frac{175{\cdot}07 \times 63{,}891{,}374}{11{,}630} = 961{,}776 \text{ pounds feet}$$

for the duty of one pound of coal.

The duty to be obtained by the contract must be equal to 95,000,000 pounds lifted one foot high for every 100 pounds of coal consumed in the boiler furnaces. Both results above are in excess of the requirements. The average of the two, or fifty-seven hours, gives 96,186,979 pounds lifted one foot high by 100 pounds of coal.

In conclusion, it has been our aim to give as fully as possible all the data acquired and facts arrived at, with such deductions as were necessary by the terms of the contract, or explanatory of the working of the engine, and readily comparative with the results of others. With regard to material and workmanship, the engines are strong, compact, well made, and, in disposition of material, good examples of mechanical engineering, and in their future working we feel sure that they will be serviceable and economical, and that the duty now arrived at could be readily surpassed after longer working and acquaintance with the machines and their appliances.

Yours, respectfully,

(Signed) W. E. WORTHEN,
J. C. HOADLEY,
JOS. P. DAVIS.

ENGINE B.—UPPER END.

MAY 6, 1876, 11.30 A.M. ELLIOTT INDICATORS. BAROMETER, CORRECTED, 30·009 IN. = 14·76 LBS.

PART OF STROKE.	Volumes in terms of Volume of High-Pressure Cylinder.	Measured ordinates, Pressures absolute.	Temperature, Fahrenheit.	Adiabatic curve begun at cut-off, P. 104·7.	Isothermal curve begun at cut-off, P. = 104·7	Adiabatic curve begun at 11 times the fill, P. = 16·96.	
0·0	·0256	104·7	330 9°	.....	.....	.....	
0·5	·0756	104·7	330 9	.....	.....	.....	
·1	·1256	104·7	330·9	.....	.....	.....	
·15	·1756	104·7	330 9	.....	.....	.....	
·2	·2256	104·7	330 9	161·7	157·6	.....	
·25	·2706	104·7	330 9	130 7	129·0	.....	
·3	·3256	104·7	330·9	109·5	109 2	.....	
Cut-off.....	·3396	(104·7)	(330 9)	104·7	104·7	1 = 118·6	(Cut-off)
·35	·3756	93·0	332·4	94·1	94·7	1¼ = 101·4	
·4	·4256	81 1	312·8	82·4	83·5	1½ = 83·6	
·45	·4756	72·6	305 2	73 2	74·8	1¾ = 70·9	
·5	·5256	65·5	298 3	65 8	67·7	2 = 61·6	(Exactly 0·65 H.P.)
·55	·5756	60·0	292·5	59·8	61·8	2¼ = 54·3	
·6	·6256	55·1	287 0	54·7	56·8	2½ = 48·6	
·65	·6756	51·2	282·3	50 4	52·6	2¾ = 43·9	
·7	·7256	47 6	279 8	46 7	49·0	3 = 40·0	(Very near Level H. P. = 1·0256)
·75	·7756	44 9	294·2	43 5	46·0	.....	
·8	·8256	42 3	270 5	40·7	43·1	4 = 29·5	(Very near 0·05 L.P)
·85	·8756	40·2	267·4	38 3	40 6	.....	
·9	·9256	38 4	264 7	36·1	38·4	5 = 23·25	(Very near 0·15 L.P)
·95	·9756	37·0	262 5	34·1	36·5	.....	
1·0	1·0256	35 8	230·5	32·4	34·7	6 = 19·2	
Means.....	.....	71·37	{ 300·285 lbs. = 57·5	.....	.....	.....	
.....	.....	.....	.....	.....	.....	7 = 16·3	
.....	.....	.....	.....	.....	.....	8 = 14·1	
.....	.....	.....	.....	.....	.....	9 = 12·45	
Cross Pipe	1·1248	.....	.....	29·3	31·6	.....	
0·0	1·1731	29·9	249·4	28·1	30·3	10 = 11·1	
·05	1·3521	24·9	239·8	24·1	26·3	.....	
·1	1·5311	21·7	232·3	21·1	23·2	11 = 10·06	Starting-point.
·15	1·7101	19·5	226·6	18 8	20·8	.....	
·2	1·8892	17 8	221·8	16·9	18 8	12 = 9·17	
·25	2·0682	16·3	217·2	15·4	17·2	.....	
·3	2·2472	15·2	213·7	14·1	15 8	13 = 8·42	
·35	2·4262	14·1	209·9	13·0	14·7	.....	
·4	2·6052	13·3	207·0	12·0	13·6	14 = 7·79	Near end of diagram.
·45	2·7842	12·6	204·3	11·2	12·8	.....	
·5	2·9633	11·9	201·5	10·5	12·0	.....	
·55	3·1423	11·4	199·4	9·9	11·3	.....	
·6	3·3213	10·9	197·3	9·3	10·7	.....	
·65	3·5003	10·5	195·5	8·8	10·2	.....	
·7	3·6793	10·1	193 6	8·3	9·7	.....	
·75	3·8583	9·7	191·8	7 9	9·2	.....	
·8	4·0373	9·3	189·8	7·5	8 8	.....	
·85	4·2164	8·9	187·8	7·2	8·4	.....	
·9	4·3954	8·5	185 6	6·9	8·1	.....	
·95	4·5744	8·2	184 0	6·6	7·8	.....	
Return....	4·5903	(8·0)	.....	.....	.....	.....	
1·0	4·7534	5·4	166·4	6·3	7·5	(At 4·7576)	
Means.....	.....	14·1425	{ 205·315 = 12·855 lbs.	.....	.....	.....	

ENGINE B.—LOWER END.

MAY 6, 1876, 11.30 A.M. ELLIOTT INDICATORS. BAROMETER, COUNTED, 30·099 IN. = 14·78 LBS.

PART OF STROKE.	Volumes in terms of Volume of High-Pressure Cylinder.	Measured ordinates, Pressures absolute.	Temperatures, Fahr., °.	Adiabatic curve begun at cut-off = vol. = ·35 P. = 105·3.	Isothermal curve begun at cut-off, P. = 105·3.
0·0	·0231	106·6	332·2	.....	.....
·05	·0731	106·6	332·2	.....	.....
·1	·1231	106·5	332·1	.....	.....
·15	·1731	106·3	332·0	.....	.....
·2	·2231	106·0	331·8	172·5	167·6
·25	·2731	105·6	331·5	139·1	136·9
·3	·3231	105·4	331·4	116·4	115·7
Cut-off.....	·3500	105·3	.....	105·3	105·3
·35	·3731	99·5	327·2	99·9	100·0
·4	·4231	87·4	317·0	87·4	88·4
·45	·4731	78·5	310·5	77·6	79·0
·5	·5231	71·0	303·7	69·7	71·5
·55	·5731	65·0	297·8	63·3	65·2
·6	·6231	59·9	292·4	57·9	60·0
·65	·6731	55·6	287·6	53·4	55·5
·7	·7231	51·9	283·2	49·5	51·7
·75	·7731	48·4	278·8	46·1	48·8
·8	·8231	45·6	275·1	43·1	45·4
·85	·8731	43·4	272·1	40·5	42·8
·9	·9231	41·2	268·9	38·2	40·5
·95	·9731	39·4	266·2	36·1	38·4
1·0	1·0221	38·0	264·0	34·2	36·5
Means.....	.....	74·775	{ 303·48 = 70·80 lbs.	.....	.....
0·0	1·1040	30·9	251·6	31·5	33·9
·05	1·2768	23·7	237·1	27·0	29·3
·1	1·4497	20·3	230·3	23·6	25·8
·15	1·6225	18·9	224·9	21·0	23·0
·2	1·7953	16·1	216·6	18·3	20·8
·25	1·9682	14·7	212·0	17·1	19·0
·3	2·1410	13·5	207·7	15·6	17·5
·35	2·3138	12·6	204·3	14·4	16·2
·4	2·4867	11·7	200·7	13·3	15·0
·45	2·6595	11·1	198·2	12·4	14·1
·5	2·8324	10·4	195·1	11·6	13·2
·55	3·0052	9·9	192·7	10·9	12·4
·6	3·1780	9·4	190·3	10·3	11·8
·65	3·3509	9·0	188·3	9·7	11·2
·7	3·5237	8·6	186·2	9·2	10·6
·75	3·6965	8·4	185·1	8·7	10·1
·8	3·8694	8·0	182·9	8·3	9·7
·85	4·0422	7·7	181·1	7·9	9·3
·9	4·2150	7·4	179·7	7·6	8·9
·95	4·3897	7·0	176·9	7·3	8·5
Return.....	4·4104	(0·8)	.....	.....	.....
1·0	4·5607	4·1	154·0	7·0	8·2
Means.....	.....	12·295	{ 199·645 = 11·45 lbs.	.....	.....

ENGINE B—UPPER AND LOWER ENDS—EXHAUST LINE.

MAY 6, 1876, 11.30 A.M. ELLIOTT INDICATORS.

PARTS.	UPPER END. Measured Volumes.	Measured Pressures.	Temperature, °		LOWER END. Measured Volumes.	Measured Pressures.	Temperatures, °	
0·0	·0256	63·0	295·7	0·0	·0231	75·4	307·8	
·05	·0756	31·5	253·1	·05	·0731	29·2	248·7	
·1	·1256	17·7	220·8	·10	·0231	15·2	213·7	
·15	·1756	11·4	199·4	·15	·1731	9·6	191·8	
Closure	·2006	(9·2)	.....	Closure.	·1888	(8·5)	.....	
·25	·2256	9·3	190·1	·2	·2231	8·3	184·5	
·25	·2756	9·7	192·5	.....	·2731	8·5	186·6	
·3	·3256	10·1	193·7	·3	·3231	8·7	186·7	
·35	·3756	10·5	195·5	.....	·3731	9·0	188·3	
·4	·4256	10·9	197·4	·4	·4231	9·5	190·8	
·45	·4756	11·5	199·9	.....	·4731	10·0	193·2	
·5	·5256	12·1	202·4	·5	·5231	10·5	195·5	
·55	·5756	12·8	205·1	.....	·5731	11·2	198·6	
·6	·6256	13·6	208·1	·6	·6231	11·9	201·5	
·65	·6756	14·6	211·6	.....	·6731	12·9	205·5	
·7	·7256	15·7	215·8	·7	·7231	14·0	209·6	
·75	·7756	16·9	219·1	.....	·7731	15·2	213·7	
·8	·8256	18·3	223·2	·8	·8231	16·8	218·8	
·85	·8756	20·1	228·2	.....	·8731	18·9	224·9	
·9	·9256	22·2	233·5	·9	·9231	21·0	230·5	
·95	·9756	25·3	240·7	.....	·9731	24·2	238·2	
1·0	1·0206	30·5	251·2	1·0	1·0231	31·0	252·1	
Means	.....	17·0475	215·2775 = 15·70 lbs.	.....	.....	15·8925	209·9775 = 14·12 lb.	215·28 209·98
								2)425·26
Means of both ends	.....	.....	212·63	.....	.....	.....		212·63
Jackets	.....	.....	330·90	.....	.....	.....		330·96
Difference	.....	.....	.....	.....	.....	.....		118·33
Cross Pipe	1·1248	.....	.....	.....	.....	.....	.....	
0·0	1·1731	5·9	169.3	0·0	1·1040	8·6	186·8	
Closure	1·2231	(1·6)	.....	.....	.....	.....	.....	
·05	1·3521	1·6	116·6	0·5	1·2768	2·3	130·9	
.....	.....	.....	.....	Closure.	1·3563	(1·4)	.....	
·1	1·5311	1·6	116·6	·1	1·4497	1·4	111·7	
·15	1·7101	1·6	116·6	.....	1·6226	1·2	109·3	
·2	1·8892	1·7	119·0	·2	1·7953	1·3	109·3	
·25	2·0682	1·7	119·0	.....	1·9682	1·3	109·3	
·3	2·2472	1·7	119·0	·3	1·1419	1·4	111·7	
·35	2·4262	1·7	119·0	.....	2·3138	1·4	111·7	
·4	2·6052	1·8	121·4	·4	2·4867	1·4	111·7	
·45	2·7842	1·9	123·8	.....	2·6595	1·5	114·1	
·5	2·9633	1·9	123·8	·5	2·8324	1·5	114.1	
·55	3·1423	2·0	126·3	.....	3·0052	1·5	114·1	
·6	3·3213	2·1	127·8	·6	3·1780	1·5	114·1	
·65	3·5006	2·2	129·3	.....	3·3509	1·6	114·1	
·7	3·6793	2·3	130·9	·7	3·5237	1·6	116·6	
·75	3·8583	2·3	130·9	.....	3·6965	1·7	119·0	
·8	4·0373	2·4	132·4	·8	3·8694	1·8	121·4	
·85	4·2164	2·5	133·9	.....	4·0422	1·9	123·8	
·9	4·3954	2·6	135·5	·9	4·2150	2·0	126·3	
·95	4·5744	2·8	138·6	.....	4·3879	2·2	129·3	
.....	4·7060	3·1	150·8	.....	4·5089	2·5	.....	
1·0	4·7538	3·8	.....	1·0	4·5807	3·2	143·9	
Means	.....	2·1625	127·0225 = 2·05 lbs.	.....	.....	1·825	119·5175 = 1·68 lb.	127·02 118·82
								2)245·84
Means of both ends	.....	.....	.....	.....	.....	.....		122·77
Jackets	.....	.....	.....	.....	.....	.....		330·96
Difference	.....	.....	.....	.....	.....	.....		208·19

FIG. 1.

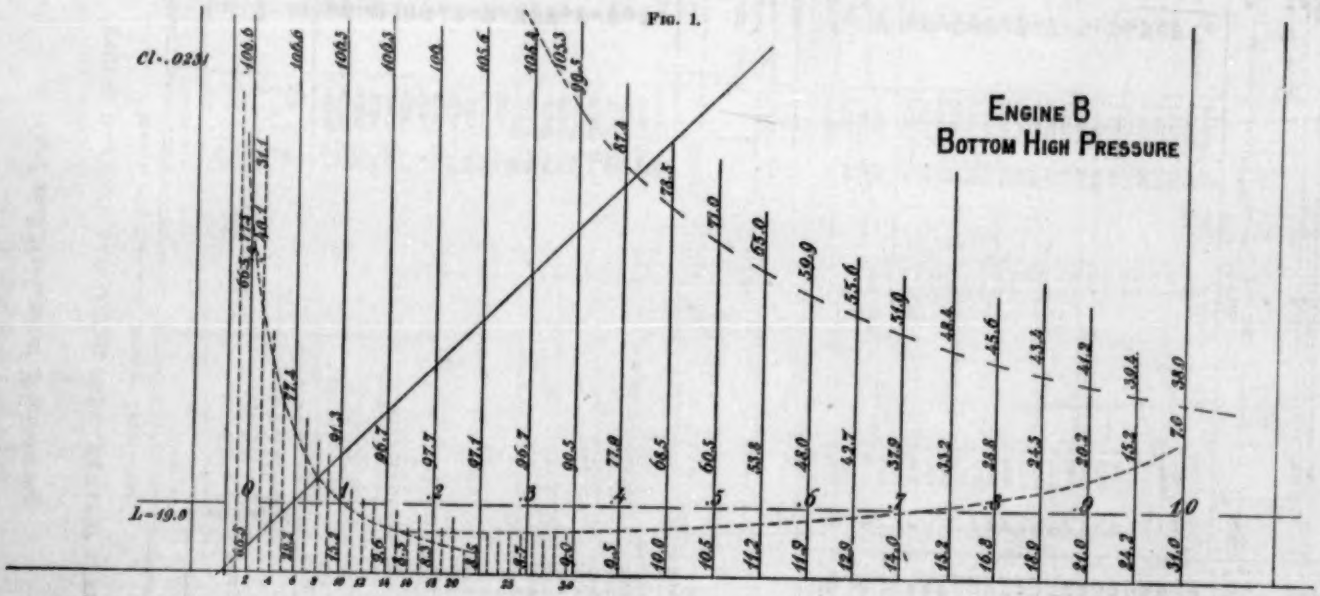
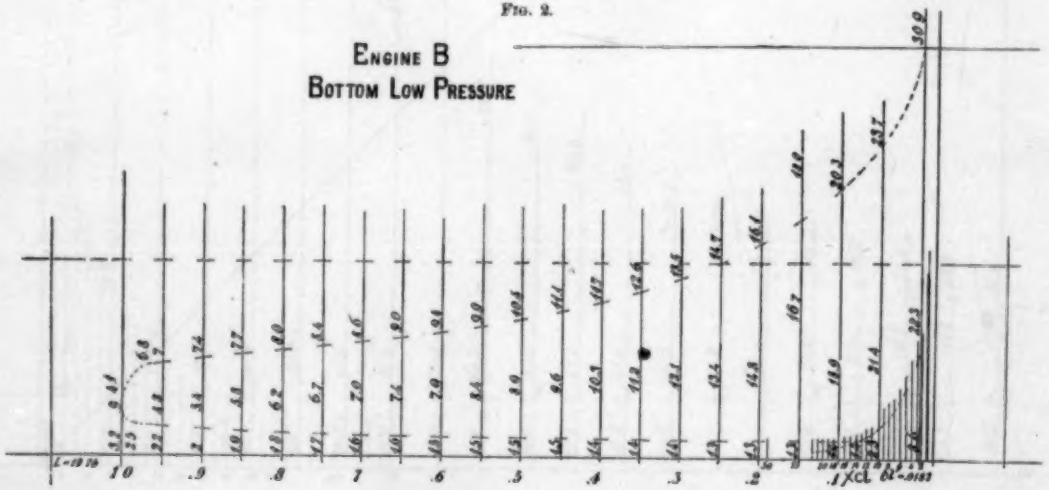


FIG. 2.



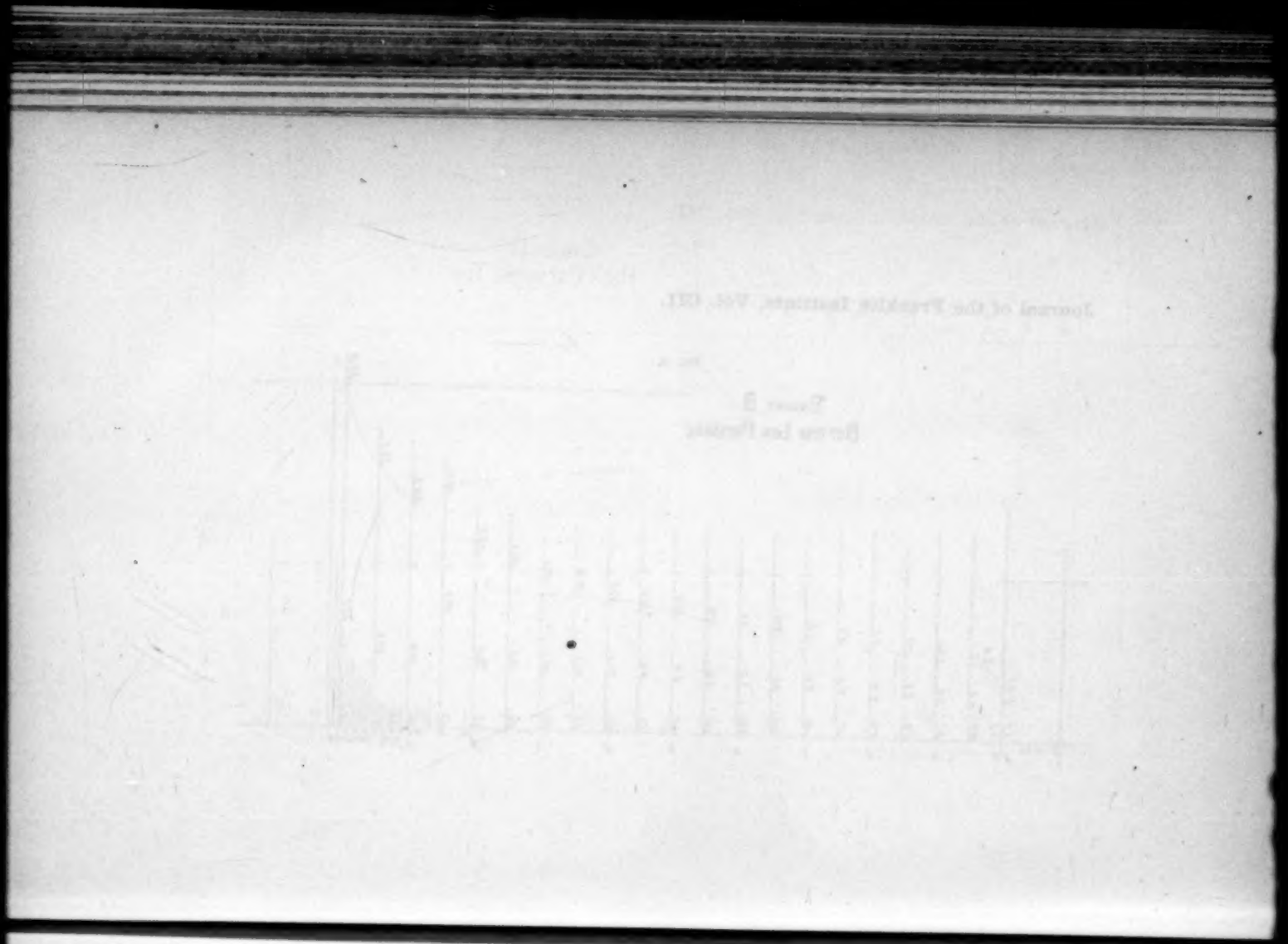


FIG. 3.

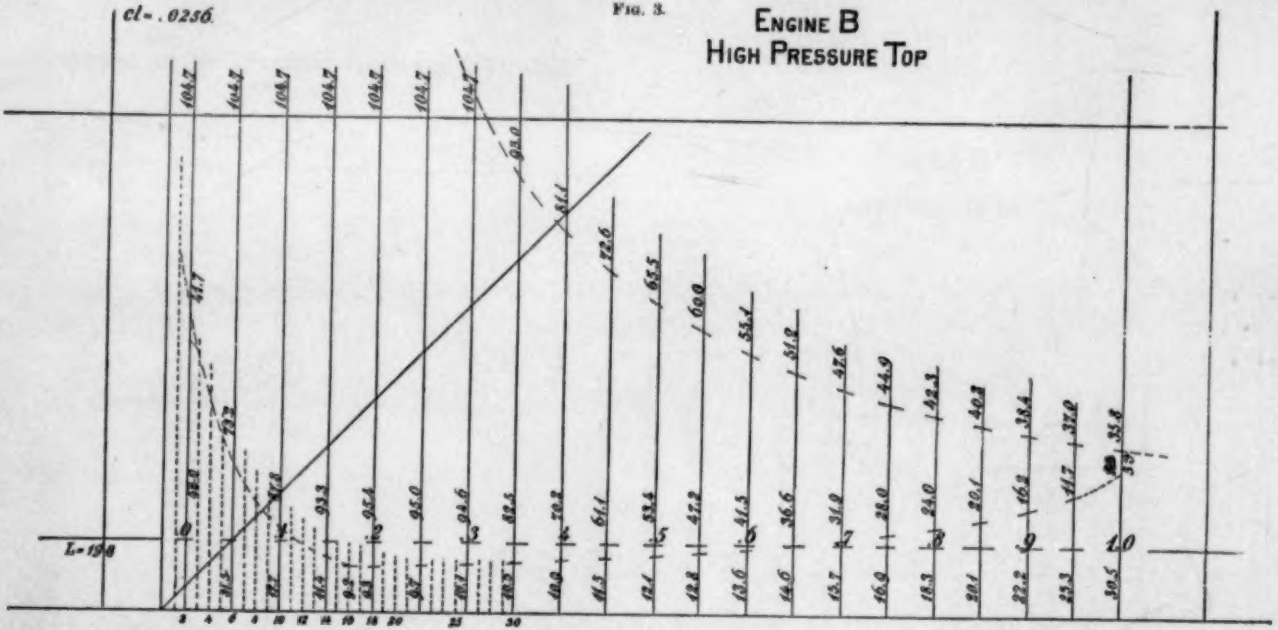
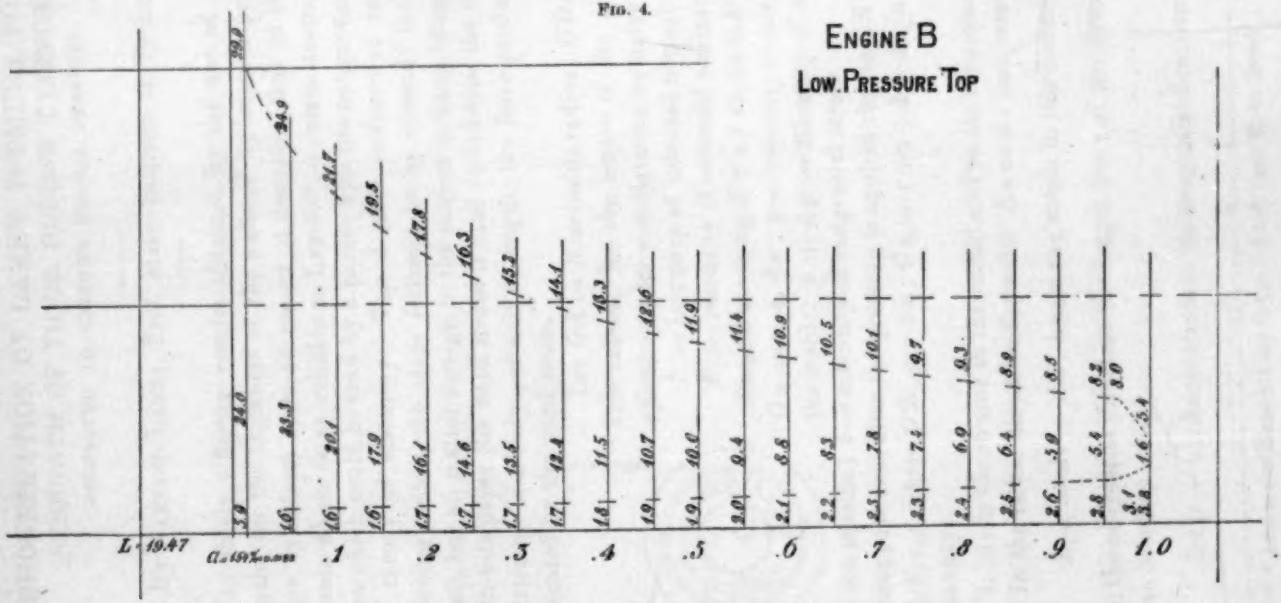


FIG. 4.



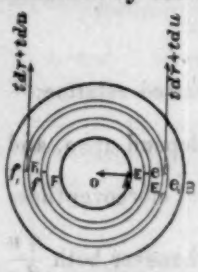
DEMONSTRATION OF LAMÉ'S FORMULA FOR THE STRENGTH OF THICK HOLLOW CYLINDERS

SUBJECTED TO UNIFORM NORMAL PRESSURE.

By GAETANO LANZA, Prof. Mass. Institute of Technology.

The widely differing results obtained by the use of the various formulæ for the thickness of the walls of hydrostatic presses (thick hollow cylinders) seem to render it desirable that in the case of a formula which is as reliable as Lamé's*, a demonstration should be given which could be read by a person who has not previously studied the theory of elasticity. This I have endeavored to do in the following article, the steps followed being virtually those taken by Lamé, but all matter foreign to the subject in hand being eliminated.

In this paper the word *strain* is used to indicate the elongation or shortening of a body per unit of length: the force producing it being indicated by the word *stress*.



Let $OA = R$ = inside radius; $OB = R_1$ = outside radius; let the length of the portion of the cylinder under consideration be unity; let

P = intensity of internal normal pressure;

P_1 = intensity of external normal pressure.

Assume any ring $EFef$ where $OE = r$, $Oe = r + dr$; p = intensity of normal stress on the inside; $p + dp$ = intensity of normal stress on the outside; t = intensity of tangential stress.

Suppose that after the pressure is applied the ring $EFef$ becomes $E_1F_1e_1f_1$ where $OE_1 = r+u$; $Oe_1 = r+u+dr+du$ (u being a small quantity).

I. *As to the strains in the radial and in the tangential direction.*

In the radial direction the width $Ee = dr$ has become:

$$E_1e_1 = dr + du;$$ hence the *strain* in this direction $= \frac{du}{dr}$.

In the tangential direction the length $2\pi r$ of the circumference EF has become:

$$2\pi(r+u);$$ hence *strain* in the tangential direction $= \frac{2\pi u}{2\pi r} = \frac{u}{r}$

* "Leçons sur Elasticité des Corps Solides," par M. G. Lamé.

II. *To determine the relation between p, t, and r consistent with equilibrium.*

Consider the forces acting on the upper half ring $E_1 F_1 e_1 f_1$;

1st, upward force due to internal pressure: $= 2p(r+u)$*;

2d, downward force due to external pressure:

$$= 2(p+dp)(r+u+dr+du);$$

3d, tangential stress (represented as acting upward):

$$= 2t(dr+du).$$

(In the ordinary case when there is no external pressure on the cylinder, dp and p have contrary signs, and $2t(dr+du)$ is a downward force and consequently a hoop tension); hence for equilibrium we must have:

$$2(p+dp)(r+u+dr+du) - 2p(r+u) - 2t(dr+du) = o,$$

or $2pr+2pu+2p\,dr+2p\,du+2r\,dp+2u\,dp+2d\,p\,dr+2d\,p\,du-2pr-2pu-2t\,dr-2t\,du=o.$

Cancelling $2pr$ and $2pu$ with $-2pr$ and $-2pu$ and omitting those terms that contain infinitesimals of a higher order than the first, viz.: $2p\,du$, $2u\,dp$, $2d\,p\,dr$, $2d\,p\,du$, $2t\,du$, and dividing by 2, we obtain:

$$p\,dr + r\,dp - t\,dr = o.$$

Dividing by dr, we have $\frac{dp}{dr} + \frac{p-t}{r} = o$ as the desired relation.

III. It is evident that the stresses p and t must depend upon, and therefore be, functions of the strains $\frac{du}{dr}$ and $\frac{u}{r}$; and moreover these functions must be of such a nature as to vanish whenever both $\frac{du}{dr}$ and $\frac{u}{r}$ vanish, since we know that when there are no strains there are no stresses; hence if we express the stresses p and t in series of ascending powers and products of $\frac{du}{dr}$ and $\frac{u}{r}$, the development must not contain any term independent both of $\frac{du}{dr}$ and $\frac{u}{r}$.

---

* The total upward force acting on the ring in consequence of the internal normal pressure will be the same as that acting on a section of the cylinder, made by a plane passing through its axis and the diameter $E_1 F_1$. The area of this section will be $2(r+u) \times 1 = 2(r+u)$, hence the total upward force will be $2(r+u) \times p$, or $2p(r+u)$.

Moreover since $\frac{du}{dr}$ and $\frac{u}{r}$ are themselves small quantities, we may omit all powers higher than the first, and all products of these strains, and use as a sufficiently close approximation only those terms containing their first powers; hence we may write

$$p = \alpha\left(\frac{du}{dr}\right) + \beta\left(\frac{u}{r}\right) \text{ and } t = \alpha_1\left(\frac{du}{dr}\right) + \beta_1\left(\frac{u}{r}\right)$$

where p and t are (as has been stated) the intensities of a pair of stresses at right angles to each other at any point of the ring $E_1 F_1 e_1 f_1$.

Now if the properties of the metal are independent of direction, *i. e.*, if the elasticity is the same in all directions; we ought, by interchanging coördinates and hence by interchanging $\frac{du}{dr}$ and $\frac{u}{r}$ to deduce either of the above equations from the other: hence we must have $p = \alpha_1\left(\frac{u}{r}\right) + \beta_1\left(\frac{du}{dr}\right)$. This can only be when

$\alpha_1 = \beta$ and $\beta_1 = \alpha$; hence we have:

$$p = \alpha\left(\frac{du}{dr}\right) + \beta\left(\frac{u}{r}\right) \text{ and } t = \beta\left(\frac{du}{dr}\right) + \alpha\left(\frac{u}{r}\right);$$

where α and β, in the case of a homogeneous body whose elasticity is constant in all directions, are constant quantities depending on the properties of the material.

From all the preceding we have the following three equations:

$$\frac{dp}{dr} + \frac{p-t}{r} = o \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$p = \alpha\frac{du}{dr} + \beta\frac{u}{r} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$t = \beta\frac{du}{dr} + \alpha\left(\frac{u}{r}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Differentiate (2) and we have $\frac{dp}{dr} = \alpha\frac{d^2u}{dr^2} + \frac{\beta}{r}\frac{du}{dr} - \frac{\beta u}{r^2}$.

Subtract (3) from (2) and we have:

$$p - t = \alpha\left(\frac{du}{dr} - \frac{u}{r}\right) - \beta\left(\frac{du}{dr} - \frac{u}{r}\right) = \alpha - \beta\left(\frac{du}{dr} - \frac{u}{r}\right).$$

Substitute these values of $\frac{dp}{dr}$ and $p - t$ in (1) and we have:

$$\alpha\frac{d^2u}{dr^2} + \frac{\beta}{r}\frac{du}{dr} - \frac{\beta u}{r^2} + \frac{\alpha}{r}\frac{du}{dr} - \frac{\alpha u}{r^2} - \frac{\beta}{r}\frac{du}{dr} + \frac{\beta u}{r^2} = o.$$

Cancelling $\frac{\beta}{r}\frac{du}{dr}$ and $-\frac{\beta u}{r^2}$ with $-\frac{\beta}{r}\frac{du}{dr}$ and $\frac{\beta u}{r^2}$ respectively, and dividing by α we obtain:

$$\frac{d^2u}{dr^2}+\frac{1}{r}\frac{du}{dr}-\frac{u}{r^2}=0.$$

By transposition we have: $\frac{d^2u}{dr^2}=-\left(\frac{1}{r}\frac{du}{dr}-\frac{u}{r^2}\right)$;

but $\frac{1}{r}\frac{du}{dr}-\frac{u}{r^2}$ is the differential coefficient of $\frac{u}{r}$ with regard to r, or to $\frac{d\left(\frac{u}{r}\right)}{dr}$; hence $\frac{d^2u}{dr^2}=-\frac{d\left(\frac{u}{r}\right)}{dr}$

$\therefore \int\frac{d^2u}{dr^2}dr=-\int\frac{d\left(\frac{u}{r}\right)}{dr}dr$; or performing the integration we have $\frac{du}{dr}=-\frac{u}{r}+2a$ ($2a$ being a constant whose value is not yet determined).

Multiplying by r and transposing we obtain:

$$r\frac{du}{dr}+u=2ar;$$

but $r\frac{du}{dr}+u$ is the differential coefficient of ru with regard to r or to $\frac{d(ru)}{dr}$; hence we have:

$\frac{d(ru)}{dr}=2ar$; multiplying by dr and integrating

$\int\frac{d(ru)}{dr}dr=2a\int r\,dr$, or $ru=ar^2+b$ (b being another undetermined constant). $\therefore\ u=ar+\frac{b}{r}$,

and from this equation we obtain directly the two strains, *viz.*:

$$\frac{du}{dr}=a-\frac{b}{r^2}\text{ and }\frac{u}{r}=a+\frac{b}{r^2}.$$

Substituting these in the values of p and t we have:

$$p=\alpha\left(a-\frac{b}{r^2}\right)+\beta\left(a+\frac{b}{r^2}\right)=a(\alpha+\beta)-\frac{b}{r^2}(\alpha-\beta)$$

$$t=\alpha\left(a+\frac{b}{r^2}\right)+\beta\left(a-\frac{b}{r^2}\right)=a(\alpha+\beta)+\frac{b}{r^2}(\alpha-\beta).$$

Next we proceed to determine the values of a and b, and to do this we must observe that when $r = R$, or when the thin ring is taken as the ring whose radius is $O\,A$, we have $p = -P$ (the minus sign being used because it is a compressive force), and when $r = R_1$, we have $p = -P_1$.

Making these substitutions we obtain:

$$a(\alpha+\beta)-\frac{b}{R^2}(\alpha-\beta)=-P;\quad a(\alpha+\beta)-\frac{b}{R_1^2}(\alpha-\beta)=-P_1;$$

two equations of the first degree from which to determine a and b; any method of elimination will give us:

$$a=\frac{1}{\alpha+\beta}\left(\frac{P R^2-P_1 R_1^2}{R_1^2-R^2}\right),\text{ and } b=\frac{1}{\alpha-\beta}\left(\frac{(P-P_1) R^2 R_1^2}{R_1^2-R^2}\right).$$

Substituting these values of a and b in the last value of t we have:

$$t=\frac{P R^2-P_1 R_1^2}{R_1^2-R^2}+\frac{1}{r^2}\frac{(P-P_1) R^2 R_1^2}{R_1^2-R^2},$$

which is the intensity of the hoop tension in the ring $E_1 F_1 e_1 f_1$. The greatest value of t, or the greatest hoop tension evidently occurs in the inside ring, or when $r = R$, when the maximum value of t becomes:

$$=\frac{P R^2-P_1 R_1^2}{R_1^2-R^2}+\frac{(P-P_1) R_1^2}{R_1^2-R^2}=\frac{P R^2-P_1 R_1^2+P R_1^2-P_1 R_1^2}{R_1^2-R^2},$$

and the greatest intensity of hoop tension:

$$=\frac{P(R^2+R_1^2)-2 P_1 R_1^2}{R_1^2-R^2}.$$

If the intensity of the working strength of the material be k, we must therefore have, in order to ensure safety:

$$k=\frac{P(R^2+R_1^2)-2 P_1 R_1^2}{R_1^2-R^2};$$

or, clearing fractions, we have:

$$k R_1^2-k R^2=P R^2+P R_1^2-2 P_1 R_1^2;$$

transposing and factoring:

$$R_1^2(k-P+2 P_1)=R^2(k+P);$$

dividing by $k-P+2P_1$ we have:

$$R_1^2=\frac{k+P}{k-P+2 P_1}R^2.$$

Extracting the square root $R_1=R\sqrt{\frac{k+P}{k-P+2P_1}}$, which determines the external radius when the internal radius, the outside and inside pressures, and the working strength of the material are known. In the more common case when there is no external pressure, as in the

case of the hydrostatic press, when the pressure of the external air is left out of account, P_1 is to be made equal to zero, and the above formulæ become:

Intensity of maximum hoop tension:

$$= P\,\frac{(R^2 + R_1^2)}{R_1^2 - R^2}, \text{ and } R_1 = R\sqrt{\frac{k+P}{k-P}}.$$

Hence, if in the case of a thick hollow cylinder, we have P = intensity of internal normal pressure; P_1 = intensity of external normal pressure; R = inside radius of cylinder; R_1 = outside radius of cylinder, and k intensity of working strength of the material; or, which is the same thing, = intensity of maximum hoop tension consistent with safety, we shall have:

1st, Suppose P, P_1, k and R are known, and R_1 required:

$$R_1 = R\sqrt{\frac{k+P}{k-P+2P_1}} \quad \text{when there is an external pressure,}$$

$$R_1 = R\sqrt{\frac{k+P}{k-P}} \quad \text{when there is no external pressure.}$$

2d, Suppose with the same data that the thickness of the walls be required, we shall have:

Thickness when there is an external pressure:

$$= R_1 - R = R\left\{\sqrt{\frac{k+P}{k-P+2P_1}} - 1\right\}$$

Thickness when there is no external pressure:

$$= R_1 - R = R\left\{\sqrt{\frac{k+P}{k-P}} - 1\right\}$$

3d, Suppose R, R_1 and k to be known, and it be required to determine the greatest internal normal pressure that can be safely used, and we shall have:

$$\text{Intensity of greatest pressure} = P = k\,\frac{R_1^2 - R^2}{R_1^2 + R^2}.$$

4th, If R, R_1, P and P_1 be given, and it be required to determine the actual intensity of the greatest hoop tension, we shall have:

Intensity of greatest hoop tension, when there is an external pressure:

$$= k = \frac{P\,(R_1^2 + R^2) - 2\,P_1\,R_1^2}{R_1^2 - R^2},$$

Intensity of greatest hoop tension when there is no external pressure:

$$= k = P\,\frac{R_1^2 + R^2}{R_1^2 - R_2}.$$

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 272.]

"There were two sets of purifiers, twenty feet by twenty-four feet on the floor, by five feet deep, having two-feet seals for the covers; with a thirty-inch main pipe and twenty-four inch branch to and from each set of purifiers. The purifiers had a single layer screen, each with a bed of oxide preparation, twenty inches in depth. The preparation was said to be oxide of iron, iron-borings, charcoal, and I think lime. The beds of oxide preparation in the three purifiers gave but two inches of water column as the resistance pressure, as exhibited to me; and the time of service of a bed, before it was fouled (for the full production of the works—about twenty-five thousand cubic feet per day, per set of purifiers), was said to be three to four days, or about eight millions cubic feet of gas would pass a set of purifiers before a bed would require revivification.

"The reviving of the preparation was done in a yard and in an old deserted and open retort building adjacent to the purifying-house. The material was heaped as usual, for other oxide, one day, and gradually spread, to avoid the excessive heat which attends a more complete exposure to the air.

"The odors attending this revivification were much less obvious than that accompanying the handling of foul lime at Philadelphia, although not so strong with ammonia as I have generally found at pure oxide heaps. They were using an '*enricher*' of ten per cent. of cannel coal to bring the gas up to sixteen candles quality, indicating a somewhat imperfect removal of carbonic acid.

"It should be stated here, that good Westmoreland, or other American gas-coal, will yield, with careful charging of the coal into the retorts, quite four and one-half cubic feet of gas (of sixteen candles quality) to the pound of coal; and if any coal, by weathering or otherwise, fails to give this quantity for the yield, it is customary to put in as a part of the charge, a portion of coal (like cannel) which will of itself alone be capable of giving gas of twenty-four to thirty candles quality; and this act is called '*enriching.*'

"I next visited the Mutual Gas Works, Eleventh street and Avenue B, on the East river. At these works they have in all ninety-five benches for coal-gas, with six retorts to each bench, and nine benches for naphtha-gas, also with six retorts to each bench. The retorts were 13″ by 24″ by 9′. The largest quantity of gas possible was made from the coal retorts—or a little over five cubic feet per pound on the average, for the year's work; and this gas was then *enriched* by naphtha-gas of forty candles quality, to bring the whole gas delivered from the holder up to twenty candle quality.

"The usual work of the retort-house here, presented no subject for comment. The washer and condenser rooms might have been a parlor for all the odor allowed to escape; the washing was done partly or wholly with ammonia water. There were two sets of purifiers, each twenty feet by twenty-four feet on the floor, by three feet deep, with twenty inch seals. In these purifiers there is but one layer of an oxide preparation, twenty-eight inches in depth.

"The preparation was a secret one, perhaps patented, and the gas was perfecty satisfactory for sulphur purification, the same prepared material had been in use over a year, and the purifiers required changing once a week or so.

"An inspection of the revivifying floor was much more satisfactory to the nostrils than that previously made at the New York Gas Works, but a slight gas-effluvia was present—that is, such a smell as attends gas-lime as distinguished from the ammonia vapors of pure oxide of iron revivification. I came away from these works without a trace of odor in my hair or clothes; while the result of two visits, of similar duration, at the Market street works, was, that at both times the odor brought away was persistent and obnoxious to an excessive degree, remaining attached to clothing for two or three days afterwards.

"It is proper to say, that, as naphtha-gas is used for enriching, the gas of the Mutual Company is, in some measure, independent of the presence of non-luminants, since a little more of the naphtha-gas will overcome this cause of imperfection; and, also, that the naphtha-gas is an experiment of yet undetermined result. Former attempts to supply mixed gases and '*carburetted gas*' have terminated unfortunately, from troubles of distribution in the mains or services, or in burning, or by cost of production, or in some unhappy way, to most parties interested.

"These examples will serve to show that some processes of oxide-of-iron purification are practiced in the United States, and that they are comparatively devoid of objectionable smells. The managers of the two works here instanced, state that the cost of oxide-of-iron purification is much less than half that of lime purification.

"In the quotations from my notes upon the use of oxide of iron for purification, allusion is only made to the avoidance of odor, and no definite description is given of the process of revivification and its products. To supply that want of completiveness of the notes, I will state, the material is removed from the discarded purifiers and wheeled in barrows to a covered floor, where it is first piled in a heap three to five feet in depth. So soon as it is exposed to the air, it commences to heat, and it is therefore banked at first, in order to give a surface exposure only. The heating is attended with a copious effusion of ammonia gas, with a trace of naphthaline odor, and a little steam from evaporation of moisture from the oxide, which is usually damp from condensation from the gas. The next day after making the heap, it will be sufficiently cooled to be turned over into rows, and on the following day to be spread in a thin layer. If the floor is large enough to allow this spreading to form a layer of two to three inches thickness, no further turning over is requisite; but the oxide must be raked once or twice on the third day, and if the layer be thin and the oxide manipulated at the proper time, it will have been *revivified* at the end of the third day. The effusion of ammonia occurs only when the oxide is turned over or disturbed, and is of short duration (a few minutes only) after the turning or spreading ceases. The principal chemical changes are substantially inodorous.

"Some attempts have been made to revivify the oxide in the purifiers without moving it, by admission of air through suitable connections, but they have resulted in failure (I am told), in consequence of the great heat evolved when the pressure of air is sufficient to pass it through the bed of foul oxide.

"It must be remarked, that the resistance of flow of gas through the purifiers is much greater for the general system of oxide purification than for lime purification; but it has been shown that the requisite apparatus for impelling the gas already exists at the Market Street works, and the question of additional power needed to effect the purpose is really insignificant, as the movement of all the gas possible to be made at these works at any time, under

eighteen inches of water-column pressure, will not exceed the performance of a ten horse-power engine.

"The process of oxide-of-iron purification results in great saving of expense to the gas-maker. At the New York Gas Works it was asserted that the entire cost of purification did not exceed five-eighths of a cent per thousand cubic feet of gas made. It is unquestionable that the use of the oxide process would result in great profit to the Gas Trust from saving of labor and of crude material, and I believe would be highly advantageous to the consumers, in the improvement of the quality of gas made, the value of which would far more than recompense the cost of introducing the process.

"There is yet another way to avoid the nuisance proceeding from dry-lime purification, which is exhibited at the works of the Manhattan Gas Company, visited by me on the 16th and 17th of March (inst.) The North River Station of the works of the Manhattan Gas Company of New York, is located on the blocks of ground west of Tenth Avenue, on West Eighteenth and Seventeenth Streets and adjacent streets. Omitting any general description of the works, only to say that the condensing and washing house was devoid of the least possible odor, I will proceed to a particular account of the system of ventilation of the foul-lime resulting from dry-lime purification, there in successful operation. At these works they have (for the one thousand and thirty-two retorts in the benches, eight hundred and forty—highest number in use at one time) three sets of purifiers, seventeen feet by twenty-two feet on the floor, by three and one-half feet deep, with seven layers of lime in each, and the usual connecting pipes of inlet and outlet.

"Besides these usual pipe connections for gas, they have likewise connected to the bottom of each purifier, a sixteen-inch pipe with a suitable stop-valve; these pipes join into a twenty-four inch main pipe, and the latter connects to an exhauster, in this instance a species of screw-fan, five feet in diameter. From the exhauster, a twenty-four inch pipe leads to a jet-washer, which corresponds in construction to that before described at Market Street works, only it is but one-fourth the length (that is, ten feet in lieu of forty feet on the floor), the height and width being about the same as the Philadelphia washers. All this part of the apparatus is in close proximity to the purifying-house. From the washer, the pipe continues to a drain-pipe three feet high by two feet wide (egg shape), which leads

under the roadway of West Seventeenth Street, nearly one thousand feet, to a deodorizing building. This deodorizing building has two closed deodorizing-*rooms*, with only a doorway for entrance, and on the floor of each room is a *brick* deodorizer-box, without cover. These boxes are thirty feet long by sixteen feet wide by three and one-half feet deep, and have seven layers, of similar construction to those used in usual dry-lime purifiers. Branches from the main drain-pipe, controlled by valves, open into the bottoms of the brick purifiers; and openings, also controlled by valves, from the upper part of the rooms, lead to a chimney seventy feet high. The screens are covered with ventilated *spent-lime*, about one-tenth of all the lime being used at these secondary purifiers. The purpose of this apparatus is the *ventilation* of the foul lime in the purifiers, and it is effectual in this way:—

"When a purifier is ready to discharge, and is shut off as usual from the gas works by the centre valve, the cover is lifted from the seat and suspended about one inch above the box. The valve of the ventilating pipe is opened and the ventilating exhauster started. Air is sucked into the purifier from the top, and the foul lime is ventilated for one and a half hours, at the end of which time it will be found decomposed and deodorized to such an extent that it can be properly denominated spent-lime; at all events, it is devoid of any marked unpleasant odor, and will have ceased to possess the power of originating them. In this condition, spent-lime is really available for immediate use for agricultural purposes. During the operation, the lime in the box heats to, perhaps, 140°, and from an approximate estimate, founded on the speed of the fan (six hundred revolutions per minute), about 300,000 to 400,000 cubic feet of air will have been passed through the layers of lime.

"The wash water is brownish yellow, and not offensive; it is run off into the sewer.

"Very unexpectedly, the long drain-pipe main was found to have acted as a condenser of naphthaline, whose presence in great quantity, in foul lime, has not been before noticed. The pipe was coated with naphthaline to the extent of *five or six inches* after a year's use, and it was removed by introducing a jet of steam and blowing it through by means of the exhauster. [It would seem that naphthaline was soluble in steam or vapor of water, while it is nearly insoluble in water.]

"Having reached the secondary purifying-house, the foul air is passed through one of the *rooms* and discharged through the chimney into the open air. The deodorizing material in this case was stated to be spent-lime from the gas purifiers. It was found that pure lime had no effect on the foul air, and at the suggestion of Mr. Carl H. Schultz, chemist, New York, the *spent-lime* was employed with great success. The lime on the deodorizing screens is revived in part, by forcing *fresh* air throught it for an hour, after the operation of ventilating a gas purifier has ceased. The lime is customarily changed in the deodorizing house, for every purifier changed in the purifying house. This operation is highly satisfactory to the Manhattan Company, and answers to meet all the requirements of the New York Board of Health, which has forbidden the use of dry-lime purification at the gas works of that city.

"[§§ *Five.*] At the Market Street works, beside the manufacture of gas, there are two perpetual lime-kilns for the making of oyster-shell lime for use in the purifiers. This branch of the business is not carried on, to my present recollection, by any other gas works in this or in other countries.

"The plant is a very simple one. A stone structure, about thirty feet long by sixteen feet broad and twenty-five to thirty feet high, contains two kilns or 'stacks,' internally cylinders of eight feet or so in diameter, with the lower part reduced to perhaps three feet; square openings from one side permit access to the bottoms or hearths of the stacks. The base of the stacks is surrounded by temporary buildings or sheds. These stacks are situated between the purifying house and the Schuylkill river, and are about one hundred and fifty, or two hundred feet north of Chestnut Street Bridge; between them and the bridge, the space of wharf is utilized, first by the foul-lime dump, and next, by a pile of generally twenty thousand to forty thousand bushels of oyster-shells (or more).

"The operation of making lime in these stacks, is to charge at the top a quantity of oyster-shells, mixed with one-fourth the quantity of coke breize and fine coke dust; and at certain regular intervals some bars of iron are driven in across the tops of the openings to the hearth, and the burned oyster-shells under the bars, now converted to lime, are *drawn* out; when, removing the bars, the charge falls from bottom to top; and after the stack has once been lighted, the process of burning will go on continuously with regularity.

"At first there arises and escapes from these kilns the steam from the moisture of the oyster-shells, laden with the odors of cooked oysters, mingled with those proceeding from decayed remains; and after this, and accompanying it, escapes a volume of nearly pure carbonic acid; together with a little chlorine vapor or gas, and some small quantity of other gases. This carbonic acid proceeds from the carbonate of lime of which the oyster-shells are mainly composed, and from the combustion of the coke, which disappears altogether during the process; and as this gas, at the temperature of leaving the kiln, where the upper layer of oyster-shells and the moisture will have nearly taken up all the heat of burning the coke, which occurs at or below the middle of the stack, has about the same density as the external air, it follows that, although it may diffuse rapidly, yet it does not dissipate by ascension. I am informed by competent authority that the height of the approach of the Chestnut Street Bridge, in front of the heap of oyster-shells at the gas works, is thirty-one feet six inches above top of ground. Consequently, as the tops of these kilns are nearly at the same level as Chestnut Street Bridge (about two hundred feet distant to the southward), and of Market Street Bridge (about three hundred feet distant to the northward), any current of air up or down the river will sweep these gases and odors directly across them.

"The oyster-shell heap, near Chestnut Street Bridge, emits disagreeable odors, and, speaking of it in the mildest terms, can be generally denominated as offensive to the public. I only state the existence of the heap to complete my narration of the arrangement and occupation of the grounds of the Market Street Station of the Philadelphia Gas Works.

III. It cannot be said by any person practically acquainted with the manufacture and supply of gas, and competent to advise on the location of gas houses, that the Market Street works are judiciously situated as regards the main thoroughfares and streets of the city, although the place may give, at this time, great advantages for distribution. The barn-yard and the pig-pen are necessary adjuncts to the farm dwelling, and the farmer is happy in their contemplation; but if the county lays out a road behind the farmer's house, when his barn is outgrown he will be likely to build a new one in another place.

"It must be regarded as a grave error that the works were not removed, in place of having been reconstructed on a larger scale, a few years since.

"The holders could have been and should have been preserved, and possibly additional ones erected, but after *the entrance* of the city was established by the erection of the passenger station of the Pennsylvania Railroad, and Market Street became the important avenue, some reasonable expenditure should have been incurred to have removed the operation of making gas to some other part of the city. And this could have been done by the construction of a single five foot or six foot wrought-iron pipe main, at no enormous outlay, considering the importance of the object.

"The Beckton Gas Works, of the Chartered Gas Company of London, which are situated nearly eight miles below the centre of distribution, and where there are two thousand one hundred and sixty double-ended retorts (equivalent to four thousand three hundred and twenty retorts of the Market Street size), can be taken as an example of the recognition of the comity of the public as weighed against the right to carry on objectionable manufactures in the midst of a city, no matter how necessary to the city itself such a manufacture may be. Any person will tolerate and endure in his shop, laboratory, manufactory or avocation, odors or dust more or less unhealthy and disagreeable, but no one will desire these inconveniences at his home.

"IV. The time requisite to make the changes necessary to avoid the nuisances now proceeding from the Market street works can be stated as follows, taking up the various sources of complaint in order:—

"*First.*—The construction of a house and smoke-tower for quenching the coke can be effected the present season; certainly before autumn sets in.—The economy of quenching and handling coke by shutes would probably defray the interest of cost of house, &c.

"*Second.*—The disuse of lime purification and the substitution of oxide of iron, as used at the works of the New York Gas Company or those of the New York Mutual, could be done at once, upon procurement of oxide or 'prepared material.' I think that this change could readily be effected within one week. The introduction of the English process of purification could be done by temporary pipe connections, so as to give the use of two sets of the purifiers within

two weeks' time; and the construction of necessary additional purifiers for use of the three sets could be readily effected this present season.

"The plea of delay in getting perforated screens at the Metropolitan Works (New York), stated to have been made by the officers of that company, as appears in the affidavit of Professor C. F. Chandler, was purely a dilatory one. I do not remember ever to have seen perforated screens used with oxide of iron, and slat screens, such as are used at the Philadelphia Gas Works, are those generally if not universally employed.

"The construction of temporary sheds to cover the revivifying floor would take but a few days, and permanent structures of suitable character for the locality could easily be built this season. The profit to the gas company arising from the substitution of oxide of iron purification would probably be $4000 to $5000 per year at the Market street works alone.

"Any desired amount of oxide of iron can be procured at a week's notice; but two weeks' delay might arise in crushing or preparing it for the first start.

"*Third.*—The introduction of the system for deodorizing foul lime now used in the Manhattan Company's Works in New York could be effected in six weeks' time, if any urgency existed; or in twelve weeks' time, at leisure.

"*Fourth.*—The disuse of the lime-kilns, by the substitution of *better* lime for purification, could be effected at six days' notice, which would be the time requisite to commence the railroad deliveries of the quantities needed. The marble from which nearly pure lime can be made can be found in abundance within *fifty* miles of Philadelphia, where kilns now exist ready for burning it. A bushel of marble-lime is equal in weight and efficiency to two and one-fourth bushels of oyster-shell lime.

"*Fifth.*—The removal of the kilns to Point Breeze or elsewhere could be effected, if any urgency existed, in six weeks; but at leisure perhaps thirteen or sixteen weeks would be required."

STREET AND TRAM LOCOMOTIVES.

From *The Practical Magazine*, London, Sept., 1876.

In our number for June (page 176 of the present volume) we inserted, from the JOURNAL OF THE FRANKLIN INSTITUTE, a few paragraphs concerning the use of steam carriages on street railways and common roads. At page 188 we gave a description and engraving of Messrs. Merryweather's steam tram-carriage, lately commenced working on the Paris tramways. It occurs to us that it may be useful to present here a few connecting links of history, so as to prepare the general reader for a due comprehension of other novelties which are likely to make their appearance ere long. Railways, as we all know, have solved the problem of steam-power *vs.* horse-power, so far as regards the traction of heavy loads at high speed. It remains still to be ascertained whether this substitution ever can or will be so complete in regard to what may be called "omnibus traffic," distinguished by lighter loads, lower speed, and more frequent stoppages. It becomes, on this account, interesting to glance at the inventions which, from time to time, have been brought forward, partly for steam-traction on tramways, but more generally for use on common roads.

If we mention Sir Isaac Newton's name in connection with this subject, it is only in relation to a speculation which he made no attempt to put to a practical test. He suggested a globular vessel, placed on four small wheels, with a jet-pipe on one side and a driver's seat on the other. Steam, generated in the globe by a suitable fire, would issue from the tube and drive the little four-wheeler onward by reaction, on the principle of the rocket. Dr. Robinson, nearly a century later, communicated to James Watt an idea for the propulsion of a carriage along common roads by steam. A cask of iron-bound staves for a boiler; an iron furnace or fire-box, fed from above, immersed in the water in the cask; steam from the heated water moving a piston in a cylinder, and the piston moving a small wheel-carriage on which the cask, &c., were placed,—such was the idea; but Watt carried it no further than the sketching of a few drawings.

Of those who really advanced to the stage of an actual carriage, or at least a working model, one of the first was Cugnot, who made

a rude model, still preserved in one of the public museums of Paris, and then a carriage, which proved to be too energetic at its work, for it dashed through a brick wall and brought disfavor to its inventor. William Murdoch, about 1790, ran a steam carriage on the highway near Redruth, but the chief fact now known concerning it, is, that the Cornish miners rushed away in affright from "the fiery little monster running along the road without horses." William Symington, whose name is as favorably associated with the history of steam navigation as Murdoch's with that of gas-lighting, exhibited at Edinburgh a model of a steam carriage, the merits of which he was unable to test by reason of the wretched state of the roads. Oliver Evans, of Pennsylvania, proposed to the legislature of that state a scheme for steam traction on common roads; his plan met with no response. He was greatly laughed at for prophesying that the day would come when such carriages would attain a speed of fifteen miles an hour. Who was nearer the truth, the derider or the derided?

Early in the present century we find Trevithick and Vivian completing and running their steam carriage on the very spot where the Euston station now stands—not a bad association of ideas, it will be admitted. From the description published, it seems to have been a tolerably light and compact piece of mechanism. A carriage rested on four wheels, of which the front pair guided or steered, while the hinder part supported the greater part of the weight; a boiler and a horizontal cylinder were placed at the back of the hind axle, while rods, tooth-wheels, cranks, &c., connected the piston of the cylinder with the wheels of the carriage.

Nobody took up these schemes in earnest—war and political troubles occupied men's thoughts in other than peaceful pursuits. But a new spurt took place just about half a century ago. Mr. Griffiths employed Bramah to work out an idea of his, and to make improvements in practical details. Little is now known of the steam carriage which resulted from this partnership in ingenuity, except that there were two cylinders with pistons, a tubular boiler, and vertical springs to deaden the concussion. Another inventor, David Gordon, had firmly persuaded himself that no locomotive carriage, or steam engine on wheels, can travel up an incline. He therefore devised a strange monster, with six jointed levers to act like six legs, with bending movements to imitate those of knees and insteps, the legs alternately stepping and dangling! Another mode of overcom-

ing the supposed difficulty was by putting a steam engine inside a large iron drum, making the engine roll the drum as a squirrel rolls his cage, and a carriage to roll on after the drum.

When it was proved that a locomotive *can* travel up hill, if not steep, inventors took courage, and novelties appeared in rapid succession. Goldsworthy Gurney built a steam carriage which Sir Charles Dance "tooled" (as coaching men would call it) between Gloucester and Cheltenham. It ran to and fro four times a day, doing the distance of nine miles in about an hour. All kinds of obstacles were thrown in his way. Innkeepers, hostlers, horse-dealers, coach-makers, road trustees, interposed impediments wherever possible. Gurney and Dance were beaten; but nevertheless they obtained a favorable report from a committee of the House of Commons. The committee fairly judging the evidence brought before them, reported that the steam carriage could maintain an average speed of ten miles an hour; that it would carry twelve or fourteen passengers; that the total weight of carriage, machinery, fuel, water, passengers, driver, and attendant, might be under three tons; that the carriage, with such a load, would ascend and descend ordinary roads with facility; and that the broad wheels were less likely to cut up the roads than the narrow wheels and horses' feet of ordinary road vehicles. Whether the system would eventually be cheaper than horse-traction could not be determined on so short an experience.

Captain Ogle was another experimenter in the same line. He made a great sensation by running a new steam carriage from Oxford to Birmingham, ten miles an hour in the towns, and twelve miles in the more open country. His contrivance was a kind of mail coach for six inside passengers and eight outside, the motive power being placed in the rear of the passenger compartment. Rivals appeared in this district and in that, but all went into oblivion after a brief period of excitement. Mr. Hancock's "infant" steam coach plied for a time to and fro between London and Stratford. A steam coach under the command of Colonel Macerone, in like manner had its little day. Mr. Scott Russell (perhaps the only distinguished living representative of that group of inventors) constructed a steam carriage which plied for a time between Glasgow and Paisley. Burstall (a name that might be regarded as rather ominous in connection with such subjects), with his partner Hill, Summers and Ogle, Dance and Field, James, Heaton, Church, Squire, Hills, Sir James Anderson—all are

to be included among the inventors which turned their attention to these matters at various periods from half a century to a quarter of a century ago. Why they all failed we need not wait to say. Some of the engines were too heavy; some had difficulty in maintaining their water-feed; some did not steer readily nor stop with sufficient promptness; some frightened the horses with their noise; while others were placed beyond the reach of profit by inordinate tolls imposed by turnpike trusts.

There is still no paucity of invention of steam coaches, if the smallest encouragement be offered them. The Earl of Caithness created quite a lively sensation in Scotland a few years ago, by performing a journey which certainly was unequaled of its kind. A very ingenious steam carriage was invented by Mr. Rickett. It was a kind of hooded chaise, with a small steam engine behind it, occupying about as much space altogether as a horse and chaise; the chaise had a seat for three persons, while the engine was attended to by a fourth person, stationed in the rear. A supply of coal for fifty miles and of water for fifteen could be carried; when thus supplied, the whole affair, with four persons, weighed about a ton and a half. On a given day the Earl started off, occupying the position of driver, with the Countess of Caithness by his side, a clergyman at the other end of the same seat, and Mr. Rickett acting as stoker. On they went, starting from Inverness, and taking the mail coach road through Beauly to Dingwall, Golspie, Durabin, Helmsdale, the Ord of Caithness, Berriedale, Wick, to Barrogell Castle—a ride of 150 miles. The ascent and descent of the Ord of Caithness, one of the stiffest bits in Britain, showed that the wheels of the little vehicle took a good hold of the road.

Without touching further on these steam coaches, we may say a few words concerning the use of traction engines for dragging heavy weights over bad roads, or rough ground without any road at all. The success of these is beyond all question. One of the first was Taylor's "Steam Elephant," employed at Messrs. Laird's to drag marine boilers and other heavy masses of iron from the works to the harbor at Birkenhead. It was afterwards used in other places, usually to support a powerful crane, which lifted up heavy weights, wheeled them along, and deposited them at another spot. The "Steam Bull" was a rival to the "Steam Elephant," and used in a similar way. Bray's traction engine, at one of its early trials, carried or

drew a boiler of 30 tons, an armor-plate of 17 tons, and two other plates, all at once. One of these engines, sent out to the South American mines, rendered great service at a spot where there were literally no roads, lowering ore down from the mine to the harbor and dragging up stores. Avelong and Porter's traction engine is another of these excellent contrivances, adapted for various kinds of farm and quarry work, and as a feeder to railways along roads where the traffic would be too small to pay for a rail. Thomson's engine is also remarkable, noticeable for the thick bands of india-rubber which form the tires of the wheels, and enable them to get over rough ground without much jolting.

As to steam vehicles on the common roadways of streets in our busy towns, we are almost as much without them now as ever. The chief exception is the road-roller, used for crushing and smoothing the surface of newly macadamized carriage-ways. The legislature has hitherto discouraged rather than encouraged the appearance of "Puffing Billy" in our streets. In 1862 an Act was passed to regulate the employment of locomotives in the streets, under the belief that they were at that time coming into use. The weight and the gauge were to be limited; they were to consume their own smoke; they were to carry lights at night; they were to carry a guard as well as a driver and a stoker; and they were not to exceed a speed of five miles an hour in towns. Another statute, in 1866, made matters still more stringent, by enacting that the speed should be lessened to two miles an hour in town streets, with a man running on ahead on foot, waving a red flag, to warn persons to keep out of the way; and noisy steam whistles were interdicted. Whether commercial traffic could live under such iron rules, the future may perhaps show; steam omnibuses for passengers would obviously find no trade at two to four miles an hour.

Tramways, as we all know, had a precarious infancy in this country, but they have surmounted their preliminary troubles, and have become fairly remunerative undertakings. The high price of hay and oats gradually led the companies to inquire whether the tram cars could be safely and profitably drawn by steam-power. Foreign countries have preceded us in this application. Kohl's steam cars (an illustrated description of which appears in our last number) have, for some time, been working successfully in the streets of Copenhagen; Harding's in Paris, and others elsewhere. An arrange-

ment by Messrs. Merryweather was tried for some time in Westminster, but circumstances were unfavorable to its success. A greatly improved construction by the same makers is described on page 188, illustrated by an engraving; this has been brought into use on some of the Paris tramways. Mr. Grantham invented a steam car, which was tried experimentally at West Brompton, and is, now, we believe, working on a short bit of country road; he planned many improvements in it, but did not live to finish them. Mr. Hughes, of Loughborough, who has built many small locomotives for use on mineral railways, has recently adapted them for a tramway at Leicester. His tram locomotive has a pair of 6-inch cylinders, 12-inch stroke; as it is fed only at the beginning of each journey, there is no need for a fuel-box. Coke is used to prevent smoke; the chimney does not protrude above the roof, and the working mechanism is boxed off to avoid frightening horses. The weight of engine and car, with coke and water for six miles, is about five tons.

Within the last few weeks a trial has taken place on the Hoylake and Birkenhead Tramway, of a tram locomotive by Woods, intended for Vienna. The engine and car form parts of the same structure. Shand and Mason's patent inclined water-tube boilers are employed. The cylinders, 6-inch diameter and 9-inch stroke, are placed under the platform, and are coupled direct to a pair of steel driving wheels, 2 feet diameter. Each end of the car has its own brake, steering gear, and passenger entrance. The boiler is at one end, while the other is supported on a bogie-truck. One man can manage the driving, stopping, stoking, &c. The car will carry twenty passengers. The water tanks are placed under the passengers' seats, and the boiler can be supplied either by an injector or by a donkey engine.

Enough; the future must show whether steam or horse-power is to rule the great systems of tramways. Hitherto, those tram locomotives which have failed, have done so because the smoke and heat have annoyed the passengers, or because the noise has frightened the horses of passing vehicles, or because the sunk capital, wear and tear, and working expenses have exceeded the total outlay entailed by horse traction. This last, we suspect, will be the *experimentum crucis*, the real test that will settle the whole question. Say that a large car, carrying forty passengers inside and out, can be drawn along at a fair speed by two horses—what will be the cost of these horses, the renewal, the stable and veterinary expenses, the hay and

oats? And what the cost of steam engine, repairs, coke, water, &c.? These are sums in arithmetic which no preconceived theory can solve.

In this connection we now learn that a new steam hand car has recently been designed and constructed by Mr. Jay Noble, master mechanic for M. M. Buck and Co., of St. Louis, Mo., which is excellently adapted for the use of division superintendents, road masters, and others whose duty requires them to make frequent inspection of railway lines. The machine resembles an ordinary hand car, except that the propelling power is steam and not muscle. The floor is about 10 inches from the ground, and is beneath instead of above the axles. The boiler, which is about 3½ feet in height, with a diameter of 18 inches, is placed in the centre of the car, while the cylinder, which is horizontal, is at the right hand side and near the floor. The cylinder is 3½ by 6 inches, and the boiler is intended to carry a pressure of 140 lbs. of steam. The body of the vehicle rests on rubber springs, and rides very easily without lateral motion. Seats are arranged in front and rear, of sufficient size to accommodate six persons. The water tank occupies a space under the back seat and holds about a barrel of water, which is sufficient to run the car forty miles. On the left of the boiler the coal pan is arranged in a space about 2 feet wide, and carries all the fuel necessary for a day's run.

On a recent trial trip, the run from St. Louis to Carondelet, a distance of seven miles, was made in fifteen minutes. The inventor states that under ordinary circumstances the cost of fuel will not exceed three shillings per day. The general arrangement is excellent and reflects much credit on the designer.

Errata.—In consequence of absence of the Editor at the time of making up the editorial pages of October JOURNAL, a few typographical errors were allowed to remain uncorrected. The most annoying are upon page 225—Article, "Thallene," which should be corrected to read "Prof. Horsford"—"a green solid" and "the crystalline form." "[From whence the first tar on which Prof. Morton experimented was derived.]" This last clause should not have been in parentheses, as it was an editorial remark, not a quotation.

Chemistry, Physics, Technology, etc.

NOTES ON ENGLISH CHEMICAL MANUFACTURES.

By S. Cabot, Jr.

[From the *American Chemist*, July, 1876.]

To give an account of the chemical advance, even during a few years, in a great country like England, is no easy task, if only in a sketchy and superficial manner. Nevertheless, having had very good opportunities of seeing some of the newest processes in use in England and Scotland, I propose to run through my note books for the benefit of your readers, leaving out many particulars which would not be interesting to any but specialists, and many which are parallel to our American methods.

Sulphuric acid seems to be the starting point of almost all the larger chemical industries, therefore we will begin with that. The pure acid is made exclusively from sulphur. In the best chemical works (for instance, Mr. Riley's of Accrington, near Manchester) the sulphur is supplied through a hopper at the top of the furnace, the nitre and strong nitrous vitriol being also let into a cast-iron pan in the exit flue by means of another hopper.

The nitrous fumes are removed from the chamber gases at the end of the set of chambers by the use of a Gay-Lussac tower. Vastly the larger portion of the sulphuric acid made in England is, however, obtained by the combustion of pyrites. In addition to the much smaller first cost of sulphur thus obtained, it is in this case possible to use the Glover's towers, which cause a great saving in fuel. The principle of the Glover's tower is well known, but I will describe them as I saw several in England. They are towers made of acid-proof stone joined together by grooving the edge and then inserting a rubber rod; at the corners these rods are slit, and one is run through the other. The whole is bolted together outside with iron rods. These towers are from 30 to 40 or 50 feet high, and are filled with some acid-proof brick. At the top are two tanks, one contain-

ing chamber-acid, and the other nitrous vitriol from the Gay-Lussac tower. These acids are allowed to flow together down through the tower, while the hot sulphurous acid from the pyrites burners rises up in the opposite direction and carrying some water as steam, and much nitrous acid goes forward into the chambers. Many attempts have been made to use the Glover's tower where sulphur was burned. The reason of failure is that, as Prof. Kopp once told the writer, sulphur can never be raised to the temperature obtained by burning pyrites, as it is volatile at a much lower temperature. The acid as it comes out of the towers is not far from 55° or 60° Bé., and may be concentrated in glass or platinum stills, as is done in this country.

The greater part by far of this acid is, however, used for the decomposition of salt in the Leblanc soda process.

This decomposition of salt is done in hemispherical cast-iron pans, which are connected with absorbing towers constructed much like the Glover's towers, but filled with coke. These pans are separated by a sliding door with a muffle furnace, into which the mass is shoved while still quite liquid, and this muffle is connected with another condensing tower in which a less pure hydrochloric acid is obtained.

There is, however, a new method of accomplishing the decomposition of salt, patented by Hargreaves & Robinson. The process is, briefly, to pass a mixture of air, sulphurous acid and steam through salt in a porous condition, obtained by moistening it and then drying and breaking it up to the required size. This has the obvious advantage of doing away with the sulphuric acid chambers entirely.

The operation is performed in immense cast-iron chests heated on the outside with coal fires, and the gas from pyrites burners is put in at the bottom of one with an excess of air and some steam, it is then taken in at the top of a second one, and so on; this is of course changed about as one after the other of the chests is discharged.

The hydrochloric acid is very strong; indeed Mr. Hargreaves told me, in showing me the condensing apparatus, that in the first pipes it was stronger than by the ordinary method.

The sulphate of soda formed seems to be of good quality, and manufacturers are looking with much interest to see the result obtained by several large establishments running on this plan.

The salt in its porous condition is thought to act catalytically, causing the sulphurous acid (SO_2), which, however, would not occur

without the presence of steam to form (H_2SO_4) sulphuric acid, which in turn reacts on the salt to form (Na_2SO_4) sulphate of soda and (2HCl) hydrochloric acid.

In the preceding paragraphs I disposed, rather summarily perhaps, of the various methods of manufacturing sulphate of soda and muriatic acid. I now propose to take up the various products of the latter acid, and give a sketchy account of the methods in use in England for the manufacture of chlorine and chloride of lime.

The two prominent, almost universal, methods of producing chlorine are by the Weldon and the Deacon processes. The Weldon process is, properly, only a method of regenerating the oxide of manganese from the chloride of manganese, formed by the action of the muriatic acid on natural binoxide of manganese.

By far the larger portion of the chlorine manufactured in England is produced under Weldon's patent, 101,600,000 kilograms, or over two hundred million pounds of chloride of lime, having been put on the market during the year 1874 to 1875 in England alone.

I had the good fortune to make the acquaintance of Mr. Weldon, and with him made an excursion of a day to some of the large works at St. Helen's, near Manchester, in one of which I saw his process in operation to great advantage.

The native binoxide of manganese is decomposed in large sandstone chests with muriatic acid; to assist the operation steam is introduced through a small (earthenware) pipe. The chloride of manganese is run into a large stone reservoir while still hot. Here it is treated with a sufficient quantity of finely powdered limestone to neutralize all excess of acid; this throws down any iron that is present as the carbonate of the peroxide. The clear liquor is then pumped into the tanks, where it is mixed with an excess of hydrate of lime. It is then warmed to 55° or 75° Cent., and then a powerful blast of air is blown through pipes which open in fine jets at the bottom. The protoxide of manganese is hereby oxidized to the binoxide, which unites with the lime to a feebly combined acid manganite of the composition, $CaMnO_3H_2MnO_3$, or $\frac{Ca}{H_2}\!>\!(MnO_3)_2$. This compound is a brownish black paste which sinks to the bottom, while a clear solution of calcic chloride remains above it. This calcium chloride is sometimes treated with sulphuric acid to obtain precip-

itated calcic sulphate (Paris white) for papermakers, etc. The sediment of bi-manganite of lime is run direct into the chests of sandstone, in which it is treated with its equivalent quantity of muriatic acid. It is, however, in a state of exceedingly fine division, and therefore requires less heat to produce the reaction. The calcium of the compound (bi-manganite of lime) requires, however, two equivalents of muriatic acid, lost in the chloride of calcium, which is usually run away for the benefit of the fishes.

$$CaOH_2O(MnO_2)_2+14HCl=$$
$$CaCl_2+2MnCl_2+8H_2O+8Cl.$$

It is evident from examining the above formula that not only two equivalents of muriatic acid are lost on the calcium, but four more are lost on the chloride of manganese (afterwards changed to chloride of calcium by the addition of lime). In an attempt to avoid these losses Mr. Weldon has invented and patented another process, which I will only briefly notice, as it has not as yet proved a success in a commercial sense, I believe.

In place of lime in the regeneration of the chloride of manganese, he proposes magnesia (MgO). The solution of $MgCl_2$ (chloride of magnesium) with suspended bi-manganite of magnesia, is evaporated. As it approaches dryness muriatic acid is given off, which is condensed for further use; then a stream of air is let in and the mass is roasted in a muffle, whereupon the manganite of magnesia reacts on the chloride of magnesia and gives chlorine (mixed with air). After roasting with an excess of air, the mass becomes changed to manganite of magnesia. This is treated with aqueous muriatic acid, whereby chlorine and a mixture of chlorides of manganese and magnesia are produced, which latter mixture is treated as before. Theoretically this process is subject to no loss of chlorine, but there are many practically important obstacles to its success—the difficulty of evaporating chloride of magnesium without destroying the vessel containing it, etc. Both of Weldon's processes are at a glance nothing but indirect methods of decomposing hydrochloric acid by means of the oxygen of the air. We now come to a direct method of accomplishing the same result. This we see exemplified in Deacon's chlorine process.

This process I had the good fortune to see in Deacon's own works. It depends upon the decomposition of hydrochloric acid at high

temperatures by the oxygen of the air in the presence of a salt of copper. The gas from the converting furnaces mixed with air is passed through chambers heated outside to between 400° to 500° Cent., and filled with earthenware balls moistened with a solution of sulphate of copper. The mixture is decomposed according to the following reaction: $\underbrace{N+O}_{\text{air.}}+2HCl=H_2O+Cl+N.$

The mixture of nitrogen, chlorine and steam is cooled, whereby the steam is condensed, then washed with water to remove any excess of acid which has not been decomposed, and then passed into the lime chambers, which must have a large surface on account of the dilution of the chlorine by nitrogen and air.

The great drawbacks to this process are: first, the quantity of hydrochloric acid (HCl) left undecomposed; second, the great dilution of the chlorine. The consequence is, that most large works—Deacon's own, for instance—use both the Weldon and the Deacon process. It appears to me that the two might be combined to advantage by passing the gas from the Deacon converter through a tower filled with native manganite in lumps, and regenerating the chloride of manganese formed by the action of the muriatic acid left undecomposed in the converters by the Weldon process.

There is one other process, in use at Tennant's works in Glasgow, in use at the time I was there, at least, wherein the manganese liquor was precipitated boiling hot, and under some pressure, with powdered limestone. The precipitated carbonate of manganese was then heated on trays in ovens with a supply of air which changed the manganous carbonate to manganic oxide, with the evolution of carbonic acid. This process, however, has not been introduced into the newer portion of Tennant's works, in which Weldon's process has been substituted.

At Tennant's, also, a part of the chlorine was produced by acting on a mixture of salt and nitrate of soda with sulphuric acid. The mixture of chlorine and nitrous acid was passed through strong sulphuric acid, which absorbed the nitrous gas, while the chlorine passed forward to the lime chambers. The nitrous vitriol was used in the Gay-Lussac towers.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. cii, page 278.]

Weldon's process, lastly, is worked more rapidly than the old method, and requires a smaller number of sandstone troughs, though the latter advantage is out-balanced by the cost of the oxidation apparatus. The productive power of a sand-stone apparatus was, on the old process, 1270 kilos. of chloride of lime weekly; whilst on Weldon's method in Alhusen's works, at Newcastle, the weekly production is 4572 kilos. In the same establishment four hours are required for the oxidation of 2500 kilos. of peroxide of manganese, being at the rate of 115 kilos. oxygen per hour.

The cost of the process in England compared with the old method may be seen from the following statements of Weldon's:—

Per 1000 kilos, chloride of lime—

Weldon's Process.—Labor, 10s. to 17s.; coal, 750 kilos.; lime, 1400 kilos.; lime-stone for saturating the excess of acid, 250 kilos.

Old Process.—Labor, £2; manganese, £6; lime, 700 kilos.

The use of Weldon's process is decidedly increasing. In the beginning of 1874 the annual produce in England on this system was 50,800,000 kilos. chloride of lime, and plant for the further production of an equal quantity was in the course of erection, whilst the previous annual production on the old system did not exceed 91,440,000 kilos. In Germany the "Silesia" establishment at Saarau has carried on Weldon's process with advantage for several years. In Belgium, according to Mr. Weldon's account, the works at St. Marie d'Oignies, near Charleroi, have introduced the process. In France the same step has been taken by the St. Gobain company, whilst Kuhlmann,** Merle, and other manufacturers are preparing to

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

** On September 18th, 1874, I found in the establishment of M. Kuhlmann, no preparations for the introduction of Weldon's process.—A. W. H.

adopt the new method. In Saarau, where, as already mentioned, Weldon's process has been in operation for some years, it is carried on exactly as above described. The consumption of lime for the regeneration of material for 100 kilos. of chloride of lime is 70 to 75 kilos. inclusive of the sediment which becomes useless in preparing milk of lime. To regenerate enough for 2500 kilos. chloride of lime air is forced in for five to five and a half hours, and from 75 to 80 per cent. of the manganese present is converted into peroxide. The air-pump employed works with 45 horse power, and has a cylinder of 7·82 c.m. in diameter, and 94·16 in height. The piston makes 40 strokes per minute. The loss of peroxide of manganese at Saarau amounts to about 10 per cent. (von Kulmitz).

The above described process for the regeneration of manganese residues has one deficiency. A portion of the hydrochloric acid is used to saturate the lime of the calcium manganite, and both lime and hydrochloric acid are generally allowed to escape in the almost worthless state of chloride of calcium. To obviate this defect Weldon has planned a modification of his process, which renders it practicable to obtain as much as 62 per cent. of the hydrochloric acid employed in the form of free chlorine, whilst only a small quantity of chloride of calcium is formed as a by-product. He attains this result by decomposing the manganese solution, not with lime, but with magnesia. For this purpose the process is modified as follows:—The liquid derived from the evolution of chlorine out of magnesium manganite, containing chloride of magnesium and manganese, is evaporated at first in a pan, and then in a kind of muffle, whilst a current of air is constantly passed through. Towards the end of the evaporation the chloride of magnesium, under the influence of watery vapor, yields hydrochloric acid, which is condensed. After the liquid has been evaporated to a certain consistence the salts are drawn upon a hearth, where they are roasted in a current of air. Here chlorine is evolved, diluted with air, and is combined with milk of lime in a scrubber, whilst manganite of magnesium remains behind. The latter is then used with hydrochloric acid for the development of chlorine, and passes again through the same rotation as a mixture of chlorides of magnesium and manganese. The hydrochloric acid, which is given off about the end of the evaporation, is exactly sufficient to evolve concentrated chlorine from the solution of chloride of lime, into which the diluted chlorine obtained by roasting the residue from the evapo-

ration has been transformed. Hence only that part of the hydrochloric acid is lost which is consumed in decomposing the hypochlorite of lime, whilst 62 per cent. of the chlorine which enters the process in the form of hydrochloric acid is utilized in the free state. In this manner it is possible to obtain 1000 kilos. chloride of lime with the hydrochloric acid evolved from 700 kilos. of common salt. The magnesia and manganic oxide are not consumed, but merely play the part of transferrers of oxygen.

Preparation of Chloride according to Deacon.—If Weldon has succeeded in preparing chlorine from hydrochloric acid in a continuous process without, theoretically at least, requiring more than one initial charge of native manganese, the problem of converting hydrochloric acid into free chlorine, without the formation of any by-products, has been much more completely solved by Deacon.

It has been long ago proposed to utilize for the manufacture of chlorine the well-known property of cupric chloride to be decomposed on heating into chlorine and cuprous oxide, which latter in a current of air yields copper oxychloride; but the experiment was never carried out on the large scale. The same applies to the fact, likewise long ago known, that hydrochloric acid mixed with air, and passed over ignited porous bodies is partially converted into chlorine and water. Deacon has succeeded in founding upon the combination of both these reactions a process, which enables us to obtain chlorine continuously without the formation of any troublesome residues whatever.

Deacon observed that the decomposition between hydrochloric acid and oxygen takes place at a far lower temperature if the gaseous mixture, instead of passing simply through ignited tubes or over porous substances, is conducted over heated salts of copper, lead (except the sulphate), or compounds of manganese. The copper salts were found most effectual, so that when a mixture of hydrochloric acid with an excess of atmospheric air was passed over porous bodies saturated with sulphate of copper and heated to 370° to 400°, all the hydrochloric acid was burnt to chlorine and water. In this reaction, which begins at 260°, the sulphate of copper remains unchanged if the temperature is not raised too high. Not till 425° does the formation and volatilization of chloride of copper begin. The permanence and the efficacy of the sulphate of copper can be increased by the presence of certain salts inactive in themselves, such as the sulphates of potash and soda.

A number of experiments conducted by Deacon in concert with Hurter and Carey, since the year 1867, have led to a knowledge of the conditions of the reaction of air and hydrochloric acid in presence of salts of copper.*

1. The quantity of the hydrochloric acid decomposed by a molecule of copper sulphate in gaseous mixtures of similar composition at the same temperature depends on how often the gaseous molecules pass through the sphere of action of the copper salt.

2. At all speeds of the gaseous current in long tubes of the same section, the opportunity for action in one and the same time is invariable.

3. In long tubes of different sections the opportunity of action is equal when the velocities of the currents are inversely as the squares of the diameters of the tubes.

4. In porous masses the efficacy increases directly as the speed.

5. Other conditions being equal the quantity of hydrochloric acid decomposed varies as the square root of the number expressing the proportion of the hydrochloric acid and oxygen.

6. At very high temperatures a certain quantity of chloride of copper is formed, but its amount stands in no proportion to the chlorine liberated.

7. The efficacy of the copper salt extends to gas molecules not in contact with the salts; the decomposition of the hydrochloric acid takes place, therefore, under conditions in which a material exchange between the copper salt on the one hand and the hydrochloric acid and air on the other cannot take place.

Without entering upon the experiments made to explain the efficacy of the copper salt we turn to the method of the practical execution of Deacon's process as hitherto carried out.

The hydrochloric acid is either prepared from salt and sulphuric acid in a common salt-cake furnace or from previously prepared aqueous hydrochloric acid. On a small scale the latter is preferable, as in this manner it is easy to produce a current of hydrochloric acid of always equal strength, whilst the evolution of hydrochloric acid in the preparation of salt cake is very rapid at first, and subsequently becomes slow. On the large scale this difficulty is met by allowing several salt-cake furnaces to work in a series, so that when the evolu-

* Henry Deacon. "On Deacon's Method of Obtaining Chlorine Illustrating some Principles of Chemical Dynamics." *Chem. Soc. Journ.*, 1872, 725.